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CONTEXTUAL CONSTRAINTS IN THE LANGUAGE OF THE CHILD.

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THE EXTENT TO WHICH REDUNDANCY OF LANGUAGE AFFECTS THE DIFFICULTY OF LEARNING VERBAL MATERIALS FOR CHILDREN OF SEVERAL AGES WAS STUDIED. SAMPLES OF SPOKEN LANGUAGE APPROPRIATE TO CHILDREN OF FIRST, THIRD, AND FIFTH GRADES AND ADULTS (AS REPRESENTED BY JUNIOR COLLEGE STUDENTS) FROM SIMILAR SOCIOECONOMIC BACKGROUNDS WERE COLLECTED BY MEANS OF A TAPE RECORDER. SAMPLES WERE ANALYZED FOR QUANTITATIVE DESCRIPTION. SOURCES OF WRITTEN LANGUAGE FOR THE SAME AGE GROUPINGS WERE ALSO COLLECTED IN ORDER TO (1) ASCERTAIN WHETHER ANY DECLINE IN REDUNDANCY OCCURRED WITH PROGRESSIVE LEVELS OF MATERIAL, (2) DETERMINE PREFERENCE OF CHILDREN FOR MORE OR LESS REDUNDANCY, AND (3) COMPARE UNIFORMITY OF MATERIAL FOR THE VARIOUS GRADE LEVELS OF CONCERN. AN EXPERIMENTAL STUDY OF THE EFFECT OF REDUNDANCY UPON A VERBAL LEARNING TASK, SIMILAR TO THE TASK OF READING, WAS ALSO CONDUCTED. A COMPARISON OF WRITTEN AND SPOKEN LANGUAGE WAS UNDERTAKEN TO EXAMINE VARIOUS LEARNING DIFFICULTIES WHICH ARISE BECAUSE OF DIFFERENCES BETWEEN THE TWO. CONCLUSIONS SUGGESTED THAT IT IS NO LONGER POSSIBLE TO ENTERTAIN THE THEORY THAT WRITTEN LANGUAGE IS MERELY A TRANSLATION OF SPOKEN LANGUAGE INTO VISUAL SYMBOLS. TECHNIQUES FOR EFFECTIVE TEACHING SHOULD THEREFORE BE DIFFERENT FOR WRITTEN AND SPOKEN LANGUAGES. (WB)

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Contextual Constraints in the Language of the Child

Cooperative Research Project No. 1877

Edward C. Carterette and Margaret Hubbard Jones

University of California

Los Angeles

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TABLE OF CONTENTS

Page

1. Problem 1

2. Objectives 1

3. Related Research 2

4. Procedures

A. Statistical Studies 23

1. Sources 23

a. Spoken Language 23

b. Written Language 26

2. Transcription Procedures 27

3. Statistical Methods 29

B. Experimental Studies

1. Pilot Studies and Results 33

2. Main Experiment 37

5. Analysis of Data and Findings

A. Written Texts 40

B. Natural Speech 43

C. Main Experiment 49

6. Conclusions 57

Appendices

I. Acknowledgements 67

II. Tables 68

III. Figures 120

IV. Experimental Materials 134

V. Bibliography 147

LIST OF TABLES

Page

Table 1. Proportions of each letter in Adult and Child Reading Material and Adult and Child Speech. 69

2. Product-moment correlation matrix for relative frequencies of 26 letters from Ginn Readers, Adult printed language, and First, Third, and Fifth Grade and Adult speech 70

3. Relative sequential constraint in Ginn Readers 71

4. Relative sequential constraint in Allyn and Bacon Readers 72

5. Comparison of adult and child reading material in terms of information, constraint and mean word length. . . 73

6. Relative sequential constraint in free-reading choices . . 74

7. Relative sequential constraint in free-reading choices: effect of sample size. 75

8. Relative sequential constraint in three Third-level texts. 76

9. Relative sequential constraint in three Fifth-level texts. 77

10. Relative sequential constraint in letter and phoneme transcriptions of First, Third, and Fifth Grade and Adult speech 78

11. Mean word length for readers, free-reading choices, and speech at four levels. 79

12. Mean sentence length for readers, free reading choices, and speech at four levels. 80

13. Proportions of letters in natural speech 81

14. Proportions of phonemes in natural speech. 82

15. Rank order of vowel and consonant phonemes by frequency of occurrence for First, Third, and Fifth Graders and Adults 84

16. Frequency of occurrence of phonemes in natural speech classified according to vowel and consonant categories: A--First Grade, B--Third Grade, C--Fifth Grade, D--Adult. . 86

Page

Table 17. Product-moment correlation matrix for 22 consonant phonemes from 15 sets of data 94

18. Pilot serial learning task: trigrams-words 95

19. Pilot serial learning task: words, child 96

20. Pilot serial learning task: words, adult 97

21. Pilot short-term memory: words 98

22. Pilot short-term memory: meaningless trigrams 99

23. Pilot narrative materials I 100

24. Pilot narrative materials II 101

25. Pilot recognition task: First Grade. 102

26. Pilot recognition task: Third Grade. 103

27. Pilot recognition task: Fifth Grade. 104

28. Pilot recognition task: Adult. 105

29. Main recognition experiment: analysis of variance, all S's, "new" errors 106

30. Main recognition experiment: analysis of variance, all S's, false alarm errors 107

31. Main recognition experiment: analysis of variance, children, "new" errors. 108

32. Main recognition experiment: analysis of variance, children, false alarm errors. 109

33. Main recognition experiment: analysis of variance, adults, "new" errors. 110

34. Main recognition experiment: analysis of variance, adults, false alarm errors 111

35. Main recognition experiment: all S's, modality by frequency 112

36. Main recognition experiment: all S's, frequency by reading level 113

37. Main recognition experiment: all S's, modality by reading level 114

Page

Table 38. Main recognition experiment: all S's, frequency by reading level, auditory presentation 115

39. Main recognition experiment: all S's, frequency by reading level, visual presentation 116

40. Probabilities of correct recognition and "new" errors for main auditory experiment 117

41. Probabilities of correct recognitions and "new" errors for main visual experiment 118

42. Proportions of individuals having a performance level superior to the mean performance level of reference group on ROC plots 119

LIST OF FIGURES

Page

Figure 1. Relative sequential constraint for several written texts . . . 121

2. Relative sequential constraint for two series of graded readers . . . 122

3. Relative sequential constraint in three levels of children's free-reading choices . . . 123

4. Relative sequential constraint in three texts of children's free-reading choices at Level 5 . . . 124

5. Relative sequential constraint in letter or phoneme transcriptions of the speech of First Graders and Adults and in a First Reader . . . 125

6. ROC plots for the auditory recognition task for First Graders . . . 126

7. ROC plots for the auditory recognition task for Third Graders . . . 127

8. ROC plots for the auditory recognition task for Fifth Graders . . . 128

9. ROC plots for the auditory recognition task for Adults . . . 129

10. ROC plots for the visual recognition task for First Graders . . . 130

11. ROC plots for the visual recognition task for Third Graders . . . 131

12. ROC plots for the visual recognition task for Fifth Graders . . . 132

13. ROC plots for the visual recognition task for Adults . . 133

Problem

The redundancy of language has been shown to exert a powerful effect upon the learning of verbal materials by adults. There have been some suggestions that a similar, although weaker effect may also be present in children. The general problem to be explored is to what extent the redundancy of the language affects the difficulty of learning verbal materials for children of several ages. Presumably a child, with less experience in his native tongue, would not be as strongly influenced in verbal learning by the sequential constraints of the language as would an adult who has had a great deal more experience with the language. Since learning to read is a verbal learning task, the general problem can be made more specific: does the redundancy of the language influence the difficulty of learning to read? Learning to read, however, involves both visual and auditory components, hence a further question arises: how similar are auditory and visual language? But what language are we to take as the norm: written adult language, spoken adult language, spoken child language, the language of children's readers? There has been no statistical comparison of written and spoken language, nor any comparison of child and adult spoken language. The problem of determining the redundancies of the various sub-languages is basic. Following that, the development of spoken language can be followed, and spoken language can be compared with written language at the various levels. The spoken language of the child who is learning to read can thus be compared with the reading materials he is given in terms of various descriptive statistics. Finally the influence of the sequential constraints in the language can be studied in a verbal learning task which is similar to the task of learning to read, using visual and auditory presentations of the material. In this way, a relatively new and unexplored avenue of approach to the specific psychological problems involved in learning to read will be attempted.

Objectives and Hypotheses

The specific objectives of the project were five in number, and are cited in chronological order.

1. The collection of adequate samples of spoken language at several levels of language development. The samples were designed to be representative of standard spoken American English of one region (Southern California), to be large enough in size to provide stable statistics, to be as free as possible of artificial restraints, and to be unrestricted in vocabulary. The levels chosen were designed to provide as wide a spread in language development as possible and to contain the adult norm. These samples were intended to be useful in many different studies of children's spoken language, but for the purposes of this project it was necessary to make two transcriptions from the tapes: a) letter transcriptions, and b) phonemic transcriptions.

2. Analysis in terms of information-theoretical statistics and some other descriptive statistics of both the letter transcriptions and the phonemic transcription of the spoken language samples. This was intended to provide a reliable, quantitative description of each language sample. With the information resulting from this analysis, it was possible to

compare First, Third, and Fifth Grade spoken language with adult spoken language in terms of redundancy, mean word and sentence lengths, and phoneme and letter distributions. The hypothesis formulated before the work started, was that First Grade language would be the most redundant, with a steady decrease in redundancy to adulthood. It was also assumed that words and sentences would be short at first with a similar gradual increase to adult level. No hypotheses were generated about the distribution of phonemes at the various ages, because we had no information on which to base one. We rather suspected that there would be some differences in letter distribution, but no specific hypothesis was formulated.

3. Analysis in the same information-theoretical terms of written language deemed suitable for the various stages of reading competence. This quantitative description was designed to permit comparison of text books for Reading at First, Third, and Fifth Grade levels, in order to ascertain whether there was a steady decline in redundancy and how these compared with adult reading material of varying difficulty. A second series of Readers was compared with the first to see how uniform the material would be across series for a given grade level and whether the two series progress at the same rate. Finally, a series of books children like to read was compared with the two series of Readers to see whether children prefer more or less redundancy than they get in their Readers.

4. A comparison of the written and the spoken texts was undertaken, but with due regard for the great differences between the two media. The letter transcriptions of the spoken texts were compared with the written material in terms of the statistics resulting from the previous analyses. It was hypothesized that the spoken language would be less redundant than the Readers at each level and that one of the difficulties in learning to read stems from this discrepancy in language. A subsidiary hypothesis was entertained: that children's speech would be closer to their free-reading choices than to their Readers in redundancy and other measures.

5. An experimental study of the effect of redundancy upon a verbal learning task as similar as possible to the task of reading. The hypothesis was that highly redundant material would be learned more readily than material with greater information content. It was predicted that this effect would be more prominent as the command of the language grew and that there might be little effect in First Graders, but it would be strong in adults. An interaction effect was predicted for modality of presentation, specifically that auditory presentation would be easier for younger subjects but that vision would be easier for adults.

Related Research

Since Shannon's application of information theory to English (1951) a number of authors have studied the constraints in language and their effects. Garner's book, Uncertainty and Structure as Psychological Concepts (1962), contains a review of early work. The studies most relevant to this report are the several estimates of the letter redundancy of printed English. Miller and Friedman (1957) estimated the redundancy of printed English as 42% to 61%, based on subjects' ability to restore mutilated passages. Chapanis (1954) however, using 13 passages of differing difficulty, found quite different results: with deletion of 10% of the letters, only 80% of the material was correctly restored. There were large context effects which have not been obvious in other studies, but which are relevant to redundancy of language. There were also wide individual differences, which were correlated with verbal ability. It would indeed be strange if they were not correlated, but the important implication is that the redundancy of a language sample is different for people of differing verbal ability. Garner and Carson (1960) estimated the total unilateral constraint in English from deletion of a single letter as 58%, but total bilateral constraint as nearly 100%. Carson (1961) estimated unilateral constraint as 48% (close to Shannon's estimate of 50%), of which he partitioned 81% to constraint within words and 19% to context.

Fuchs (1955) presented some data on Latin vs. English authors, and found English to be very much less redundant than Latin. The two English authors for whom he cites individual data are very difficult writers by any standards; the redundancies are 29% (Shakespeare) and 38% (Huxley). Bourne and Ford (1961) found the redundancy of subject words from a technical index to be about 50%. Burton and Licklider (1955), studying long-range constraints in English with Shannon's guessing procedure, obtained very similar results. They studied the effects of constraints over very long distances and found no measurable effect after about 32 letters. Frick and Sumby (1952) did a study of control-tower language, which must be intelligible in very noisy environments, and found it to be 96% redundant. Newman and Gerstman (1952) calculated the constraint in a 10,000 letter sample of the Bible. Their curve of constraint was not very different from Shannon's upper bound curve. They found no drop in constraint at the 5th or 6th letter, with an average word length of 4 letters, so they concluded that sequential dependency is not affected by word-breaks. Newman and Waugh (1960) studied the redundancy of the same text translated into three languages: Samoan was 57% redundant, English 41%, and Russian 47%. They also compared English texts of 3 levels of difficulty. Recalculation from their data yields the following redundancies: Bible (easy): 41.3%, William James (intermediate): 36.1%, Atlantic Monthly (difficult): 31.9%. The Shakespeare redundancy calculated by Fuchs (see above) is even lower (29%), indicative of its greater difficulty. Sumby (1960) compared the letter redundancy of control-tower language and language of newspaper editorials, using the guessing technique. He found control-tower language 75% redundant and newspaper language 56% redundant. But describing a situation before giving a control-tower message, improved the predictability considerably, that is, physical or situational context is also an important factor in the predictability of language, a point of some importance in comparing written and spoken language. He found little change in uncertainty after 8-letter contexts for this type of material, and little change with experience in using control-tower language.

Somers (1961) partitioned constraint 50% to phonetic and morphological constraints, 15% to grammatical, and 12% to logical and other contexts, but his phonetic and morphological estimates were taken from other sources (unnamed). Although Somers talks of phonemes, he is really dealing with written material. This raises a point of some interest, the prevailing fashion of studying written English but drawing conclusions about spoken English. There are several studies which purport to deal with spoken language. For example, Baddeley, Conrad and Thomson (1960) calculated sequential dependencies and prepared frequency tables for written vs. spoken language. But the spoken language analyzed was the printed text of a British radio serial, i.e., it was written first and then put into aural form. Likewise, Denes' study of 'spoken' English (1963) had as its corpus the texts of phonetic readers (intended as aids in teaching English to foreigners); again basically a written language. Finally, the monograph by Hultzén, Allen and Miron, "Tables of Transitional Frequencies of English Phonemes" (1964), has as its corpus dialogue from plays. There are undoubtedly good reasons for linguists' preferences for dealing with a neat and tidy formal language, but the psychologist and the educator need to know something about language as it is used in everyday communication. This type of informal language has not been studied in terms of constraints and no tables of simple frequencies, or digram or trigram frequencies exist for the phonemes actually occurring in natural conversational English speech.

Since it has been shown that information theory statistics reliably describe differences among languages and among texts of differing difficulty in English, it becomes of interest to apply this technique to spoken language, in order to gain some insight into the differences between written and spoken language, and to compare language at various competence (age) levels, so as to throw light on developmental changes. A more technical discussion of the mathematical treatment of redundancy and other aspects of language will be found in the section on Procedure - Statistical Methods.

Language Constraints in Perception and Learning

There exists a substantial literature relating to the effects of language constraints on the perception or learning of verbal materials. Any constraint imposed upon the sequence of any linguistic unit, i.e., any departure from equiprobable occurrence, increases the redundancy of language. The effects of redundancy upon performance have been investigated in several ways: by comparing units of high and low frequency of usage in natural language, or of high and low experimentally determined frequency, by varying the amount of context in different ways. A number of different measures of the effect of these manipulations upon performance have been used.

There is a great deal of material on the effect of frequency of occurrence in the natural language upon visual threshold for words. This has been conveniently summarized by Rubenstein and Aborn (1960), and by Pierce (1963 a). There is good evidence that words of very low frequency in English have higher tachistoscopic thresholds than words of great language frequency, other things being equal. Spielberger and Denny (1963) showed that subjects with high verbal ability did not show the same effects of language frequency as did subjects with low verbal ability, which is to be expected (cf. Chapanis (1954)).

Tulving, Mandler, and Baumal (1964) found that the probability of correct recall increases directly as a function of duration of exposure and length of context in tachistoscopic recognition. They believe that the two sources are additive.

Whether the frequency effect on threshold is due to a response bias or is a genuine perceptual effect is still a matter of dispute. Goldstein and Ratleff (1961), using a forced-choice psychophysical technique (Blackwell, 1953), which does not involve verbalizing the stimulus, replicated the work of Goldiamond and Hawkins (1958). They had two groups: one using a spatial forced-choice and the other a temporal forced-choice. Eight nonsense syllables, two each, at frequencies of 1, 5, 10, and 25 were presented. There was no frequency effect in either case. This is a very small sample of items upon which to base an important conclusion. Taylor, Rosenfeldt, and Schulz (1961), however, did find a significant frequency effect using a similar forced-choice technique for control of response bias. They believe that the question is still unanswered as to whether perception is influenced by frequency or whether it is merely that fewer partial cues are needed to identify more familiar materials.

Pierce (1963 b) found evidence of response bias in tachistoscopic thresholds. Word frequency affected thresholds only for unknown sets. Further, there was no difference between high and low frequency words in threshold for correct identification of initial letter; the difference appeared in the correct response for the whole word. The explanation given is that the subject guessed frequent words to fill in fragmentary percepts.

Newbigging (1961) set out to test Solomon and Postman's (1952) hypothesis that the high frequency bias is due to guessing of high frequency words based on part perceptions. He used 4 lengths and words of 6 frequencies of occurrence in a tachistoscopic presentation. In considering the two pre-recognition responses, he found greater letter similarity to the correct response for the infrequent than for the frequent words, which he interpreted as supporting the hypothesis. On the other hand, responses to infrequent words belong to the class of less frequently occurring words than do responses to words of high frequency of occurrence, and response times for correct response and for pre-recognition responses are longer for infrequent words. Both of these could be interpreted as perceptual effects.

Smock and Kanfer (1961) also found evidence of response bias in an experiment similar to that of Goldiamond and Hawkins but using three groups of subjects having very different mental sets. They conclude that response bias may be affected not only by experimentally manipulated frequency but also by set.

Neisser (1954) compared tachistoscopic thresholds for words studied, their homonyms, and new words. Thresholds were lower for the known set, whereas homonyms and control words were not different. He concludes that set does more than raise the probability of verbal response; it also facilitates the perception of certain specific visual patterns.

Brown and Rubenstein (1961) reported results of a study of intelligibility of 1,300 monosyllabic words, 100 from each of 13 frequency class intervals. They found the probability of a correct response to be independent of frequency when the stimulus and response words agreed in frequency interval. Response bias was considered to be a necessary condition for the frequency effect, however, the magnitude was greater than predicted. The implication appears to be that words do carry some acoustical information about their frequency class.

Havens and Foote (1963) presented some very sparse data which purport to show that competition for response is important in tachistoscopic threshold but frequency is not. Foote and Havens (1965) showed that configuration of letter patterns was a significant factor in tachistoscopic threshold with both free response and multiple-choice response, but frequency only in the free response condition. They argue that frequency is effective only where response bias can operate, whereas configuration is shown to affect perception. These results lend support to the response bias explanation of the word frequency effect (cf. Haber (1965), Newbigging (1961)).

Using German words and subjects, but using frequency counts of Engligh equivalents [sic!] Riegel and Riegel (1961) still found that the best of 40 predicters of visual duration threshold was log frequency. It is admitted by most investigators that the most frequently used source of the frequency of occurrence of words, the Thorndike-Lorge count, is extremely inadequate, particularly with respect to spoken frequencies, hence the frequency effect must be powerful. (See Rosenzweig and McNeill (1962) for a discussion of errors in The Counts.) There is also the question of how well learned a word must be before it is really familiar.

Goldman-Eisler (1957) had subjects guess words in sequence in 7 sentences. She found significant differences between words preceding pauses, those following pauses, and those uttered fluently. The pauses were related to the transitional probabilities of succeeding words, whereas fluency was related to redundancy (cf. also Goldman-Eisler, 1958, 1961a, 1961b).

Cherry (1953) found that clichés (highly redundant messages) were correctly perceived in 2 simultaneously spoken messages, even though the messages were otherwise confused.

It has also been shown that intelligibility of words in noise increased with frequency of language usage (Pollack 1962, 1963a and b), in unknown message sets (Pollack, Rubenstein, and Decker 1959). Rosenzweig (1956) found that half the variance of the intelligibility threshold was accounted for by log frequency of usage in both English and French. Rosenzweig and Postman (1957) reported the correlation between intelligibility and log frequency as -.78 for English Subjects, slightly lower for French. Rubenstein, Decker, and Pollack (1959) reported word frequency effects for unknown sets, but not for known sets. (cf. also Pollack, Rubenstein, and Decker, 1959.) This is related to the effect of context on redundancy. Savin (1963) also showed that frequency is related to intelligibility, that errors tend to be words of greater frequency (as with visual thresholds), but that the effect is evident only for short words--long words having lower thresholds in general, as Rubenstein, Decker, and Pollack, (1959, see above) found also.

Length of a word does influence its threshold. McGinnies, Comer, and Lacey (1952) found both length and the length by frequency interaction significant for tachistoscopic threshold (visual). Longer words have higher recognition thresholds than short words, but the effect is greater for low frequency than for high frequency words. Newbigging (1961) found length, frequency, and the length by frequency interaction all significant effects in tachistoscopic threshold. Longer words have higher thresholds only when they are very infrequent words, confirming McGinnies, Comer and Lacey. Howes (1957) found intelligibility thresholds (auditory) lower for longer words. Black (1952) found the number of sounds per word and the number of syllables per word significant.

Battig (1957) using a quite different technique, the "guessing game" for letters in words of 5 different lengths, found a curvilinear length effect, but stressed the importance of particular letters and the effect of the small sample of words in each frequency and length group. In any situation in which length can be perceived as such, it will have the effect of limiting the set of responses, because of the length-frequency relationship (Miller, Newman, and Friedman, 1958).

Mayzner, Tresselt, Adler, and Schoenberg (1964) had 5 groups of S's each generate 1,000 letters in 5 different tasks. The rank order correlation between their proportional frequencies and those of the Mayzner-Tresselt tables based on 87,250 letters were high: .70 to .83. Aside from concluding that their S's were not random generators, they found them highly sensitive to word length and to letter position.

Egan (1948) found correct responses in an intelligibility test highly correlated with number of sounds in a word. He also found sentence intelligibility related to the number of words in the sentence.

Korn and Lindley (1963) tested immediate memory for consonants and found a significant correlation with consonantal frequency in the language and also with experimentally determined frequency.

Peters (1936) attempted to test the effect of frequency of occurrence on recall. The differences among his frequency classes were so small as to be negligible, but he apparently consistently found differences favoring the two extremes of any set. Hall (1954) used 4 lists with widely differing frequencies of occurrence. He did find significant differences, but not between the highest two groups, where Peters' words are found. Murdock's (1960) results agreed with Hall's.

Peterson, Peterson, and A. G. Miller (1961) tested the effect of frequency in short-term memory. They found very significant frequency differences at 6 sec. delay but not at 1 sec. delay. They found no difference in latencies between nonsense syllables and words at either delay, and concluded that mediating associations are not necessary and therefore that they do not account for the frequency effect found at 6 sec. delay.

Di Mascio (1959) studied the visual learning of consonant syllables (CCC) of similar association value but of different summed letter frequencies. Recall correlated 0.95 with log frequency. When he held frequency constant and varied association value there were no significant differences in recall (Rho = .18). He also correlated Pratt (1939) trigram frequencies with Glaze association values for CVC syllables--Rho = .96. His conclusion was that frequency is the more fundamental concept.

Baddeley, Conrad, and Hull (1965) compared log letter frequency and predictability of letter sequences in determining recall, and found both significant but predictability (on the basis of their "statistical subject") better.

Lachman and Laughery (1965) had two large groups of subjects respond to each letter of the alphabet with a single letter, either (1) the next in sequence, or (2) the first association to come to mind. They found "enormous" differences between the two instructions, and also sizeable differences between their sequence norms and previously published digram tables.

Bloomer (1961), using published data, related multi-ordinality (multiple meanings), concreteness, and log frequency of 149 words to reading and spelling difficulty. He found multi-ordinality made both spelling and reading easier--that is, the more meanings a word has, the easier it is. Concreteness also made words easier to read and spell. Frequency was likewise significant. There was no relation between multi-ordinality and concreteness for these words, and only a small positive relationship between multi-ordinality and frequency. Multi-ordinality was related to ease of reading only as a function of its relation to frequency--the number of meanings did not affect word difficulty for readers. Concreteness likewise was effective only through its relationship to frequency. Zipf (1945) had found a very precise linear relationship between number of meanings and word frequency, the slope of the line being -.5. Gorman (1961) varied both the frequency and the abstractness of nouns and found both of these significant for recognition and independent. Winnick and Kressel (1965) found only frequency significant for tachistoscopic thresholds. In paired associate learning, both the frequency and the abstract-concrete dimensions were significant, but in recall only the abstract-concrete dimension was significant. Meaningfulness, as measured by the number of associations, was significantly related to the abstract-concrete dimension but not to frequency. However, if only concrete words were considered, the relation between number of associations and log frequency was high. They suggested that frequency is an important parameter in recognition and in paired-associate learning, whereas the number of associations is important for free recall because it provides more mediational links.

Johnson and Fehmi (1963) made an attempt to investigate the effect of oral-aural frequency of words by using words which have homophones. Although they found high frequency words to be learned more quickly than low, they found that the frequencies of two homophones did not add, hence concluded that there is no transfer from aural to written frequency. Since the test was visual, it hardly seems to be a convincing demonstration. Postman and Rosenzweig (1956) found some transfer from auditory training to visual test.

Underwood and Keppel (1963) found no difference between low association pairs of letters and high association pairs in retention when corrected for "degree" of learning, and concluded that there was no support for the letter interference hypothesis of forgetting. However, there was really little differences between the two sets of letters (the highs were not very high) and it has often been found that rather gross differences in frequency are necessary, hence the log frequency relation.

Postman, Turnage, and Silverstein (1964) reported some rather interesting results for running memory span. Lists of low-frequency nouns proved to have longer running memory spans than lists of high frequency nouns, but if mean number of items correct regardless of order is scored, then high-frequency nouns are superior; it is the order, not the availability of the response which is superior for the low frequency lists (cf. Horowitz (1961) and the discussion of ordering below). Since order is a characteristic of grammatical strings and language, it would be unwise to generalize from experiments not involving order.

Moore and Ross (1963) investigated context effects in running memory span. They concluded that memory for order was superimposed additively upon an order-free short-term-memory. They found recognition of novelty an important factor in producing low error scores. This is, of course, related to the finding of large errors with high frequency items in other experimental settings and our finding of lower false alarm rates with non-words than with low frequency words. Mayzner and Schoenberg (1964) had subjects learn strings of digrams consisting of high- and low-frequency consonant pairs. There was a very significant frequency effect. In addition more information about sequence was retained in the high-high digram lists.

Many years ago R. H. Waters (1939) showed that nonsense syllables containing the most frequently occurring consonants were more readily learned than those containing the least frequently occurring consonants. But he also pointed out that syllables containing consonants of high frequency were the ones with high association values. In English, of course, most of the information is carried by consonants.

Brown and Hildum (1956) studied consonantal phonemes by recognition of auditorially presented CVC syllables, varying the first consonant to produce either an English word (all of low Thorndike-Lorge frequencies), an English non-word, or a non-English word. There were significantly more English words than English non-words recognized, and significantly more of the latter than of non-English words.

Postman and Conger (1954) found that although word frequency correlated significantly with tachistoscopic threshold, mere trigram frequency did not. The implication here is that the trigram must be a unit before frequency is effective. Postman and Rosenzweig (1956) did find a frequency effect which they attributed to the frequency as a syllable in English rather than to mere frequency of juxtaposed letters.

Lindley (1960) compared serial learning for words, 2 sets of syllables of high association value of high and low 'familiarity', and syllables of low association value and 'familiarity'. One set of high association syllables contained the first 3 letters of familiar words, the others did not. There is no attention to the unit that is familiar, (cf. Postman and Rosenzweig (1956) and Rosenzweig and Postman (1958)); familiar apparently means frequent. Also there was only a single list of each sort. 'Familiarity' was found significant, but the experiment is not very analytical. Archer (1961) criticizes him for not using modern association norms, and plots the data to show a regular relationship between association value and learning.

Other sub-units of language also show this effect of frequency. Baddeley (1961) compared the ease of learning syllables which varied in meaningfulness and in "predictability" (i.e., similarity to the sequential dependencies in English), and in general found conformity to the statistical structure of English superior. R. C. Johnson (1962) has also claimed that frequency is a major variable in verbal learning, but stated that the trigrams must be syllabic units in English, not just all 3-gram counts in running text. He believes that failure to heed this point accounts for Underwood and Schulz's (1960) failure to find a relationship between trigram frequency and learning, and that their pronunciability variable merely corrects this mistake. Underwood and Postman (1960) also think unit frequency is the important variable, but the experiments are subject to so many criticisms that the results tell us nothing, and the reported results do not appear to support their conclusion.

Underwood and Schulz (1960) have summarized the earlier work on the effect of language frequency upon learning and, although the effect is clear, seem unhappy that the effect is not larger. Since there are many variables that affect verbal learning including type of stimulus presentation, type of response, prior (extra-experimental) experience, rate, and idiosyncratic material, it does not seem surprising to us. In particular, the majority of these studies use too few samples of language for repeatable results. Care is seldom taken to distinguish between auditory and visual frequency of occurrence. Conclusions are even drawn about auditory perception from visual experiments, though the reverse is not true.

Sumby (1963) found recall of serial lists presented visually to be significantly affected by Thorndike-Lorge frequency count, but there were no differences between moderately and very high, or between moderately and very low. Learning the correct order of the words was easier for the high frequency list (cf. Mayzner and Schoenberg, 1964). He also found differences in the type of associations among high frequency words (largely semantic) and low frequency words (entirely phonetic). This may be related to the fact that in short-term memory acoustic confusions are prominent with both visual and auditory presentation (Conrad, 1962, 1964; Conrad, Freeman and Hull, 1965; Conrad and Hull, 1964; Wickelgren, 1965a and b), and the suggestion that acoustic confusions are important in short-term memory, whereas semantic similarity is important in long-term memory (Dale, 1964). Low frequency words may be more difficult to store in long-term memory. In turn, there may be a relationship between these findings and those of Gibson, Bishop, Schiff, and Smith (1964), who reported that pronunciability of trigrams was more important than meaningfulness when a perceptual measure was used, but meaningfulness was better when a memory function was tested. The frequency of unit was not controlled in these experiments nor were the list idiosyncrasies.

Lloyd (1964) found that language frequency of words was a significant source of variance in short-term memory and varied with storage load. Recall errors increased as word frequency decreased, and differences were greater for low storage loads. Martin (1964), studying associated pairs of words of high, medium, or low frequency and associative strength, found frequency effects (as divorced from associative strength with which it was highly correlated) significant only for low levels of associative bonds. Peixotto (1948) claimed a significant relation between initial or terminal letter frequency and recognition when association value of nonsense syllables is partialled out. There are a number of studies of the effect of the transition probabilities of English upon the solution time of anagrams. It is found that frequency is a very significant variable (cf. Mayzner and Tresselt 1958, 1962).

The Effect of Experimentally-Determined Frequency

There exists some literature on the effect of experimentally-manipulated frequency. Underwood and Schulz (1960) have summarized the early work. Most findings support the hypothesis that mere frequency of exposure is effective in improving learning. In the one study that did not (Waters, 1939) there were very few familiarization trials, and the responses required were extremely unnatural ways of handling verbal material. Schulz's doctoral dissertation (reported in Underwood and Schulz, 1960) presented evidence that more frequently presented syllables are more easily recalled, response familiarization being more effective than stimulus familiarization. This corresponds to the response bias found in many studies of language frequency. Another contribution to the literature on experimental frequency is that of Schulz and Tucker (1962). They found that the number of stimulus familiarization trials in a paired associate learning task was related to performance only when the subjects were required to pronounce the stimulus items. The large number of uncontrolled variables make this finding difficult to interpret. Solomon and Postman (1952) found visual duration thresholds significantly affected by experimentally manipulated frequency, and Baker and Feldman (1956), using the same items and the same frequencies, found similar results for luminance thresholds.

Taylor (1958) showed two groups of subjects a set of 10 nonsense syllables 15 times. For one group a drawing of a common, meaningful object was attached to each syllable. She tested both visual duration thresholds and recognition. Neither association value of the syllable nor experimental "meaning" was a significant source of variance, but frequency did reduce thresholds. N. F. Johnson (1964) found experimentally varied frequency significant in a paired associate task with no response learning.

Sprague (1959) compared 3 groups in terms of visual duration thresholds for nonsense words which had been experienced at different frequencies (none of them very frequently). He did find frequency significant, but concluded that aural-oral frequency has no effect on visual thresholds. This is contrary to Forrest's (1957) experimental findings. However, Sprague's 3rd group had no visual training and even in his other groups the effect was barely significant. Auditory presentation reveals different list idiosyncrasies than does visual, and there is good evidence that a single list is unsafe. Weissman and Crockett (1957) found excellent evidence of transfer from auditory to visual mode. Postman and Rosenzweig (1956) found larger transfer effects from visual training to auditory test than the reverse, possibly due in part to the type of response required of the subject.

Zajonc and Nieuwenhuyse (1964) found that more frequently presented Turkish words were significantly more readily learned by Dutch subjects but that the effect of frequency is sensitive to the criterion used.

The Effect of Degree of Organization on Verbal Learning

Constraints of other sorts have been introduced into verbal learning experiments. Aborn and Rubenstein (1952) studied recall of sequences of trigrams containing various degrees of organization. They found that the number of syllables recalled increased with increased organization, but the amount of information decreased. Pollack (1953) reported similar results for auditory material. Hogan (1961) had his subjects copy messages of four different degrees of redundancy. The number of symbols copied per look increased with the redundancy of the message, but the amount of information decreased. This study shows the same redundancy effects for short-term memory as have been reported for long-term memory (cf. Aborn and Rubenstein, above). G. A. Miller (1958) showed that redundant strings were recalled better than random strings. I. Miller (1957) had subjects listen to passages at several signal-to-noise ratios. The 16 passages, 36 items long, were constructed of nonsense dissyllables by permuting 4 consonants around two vowels; four of these had 1 bit of information per item, 4 had 2 bits, 4 three bits, and 4 four bits. He found a very significant effect of amount of information and also a very significant interaction between S/N ratio and information--as noise increased the effect of increased information was much more pronounced. This relationship accounts for the extreme redundancy found in control-tower language.

Pan (1926) found that paired associates learning was improved by the presence of a context word which was logically related to the response word.

Decreasing redundancy by systematic elimination of materials is another technique used by several investigators. Miller and Licklider (1950) interrupted speech with silence and found that, with a speech-time fraction of 0.5, 5 interruptions per second provide a glimpse at every phoneme (on the average) which is sufficient for intelligibility. But they also reported that a word is likely to be missed if its initial or final phoneme is chopped off--this is in lists; with context it would not be as serious. It is also true visually, for in reading the initial letter is the most important cue.

Studies of Order of Approximation to Natural Language

Nicol and K. M. Miller (1959) deleted words in newspaper prose and had subjects restore them. Even the 12th order passage was not perfectly restored (but this was newspaper jargon, not standard English) which led them to conclude that word redundancy is less than letter redundancy (cf. the discussion of the statistics of language above). Function words were restored better than content words. This is related to the "Cloze" technique (cf. Taylor, 1953) which involves deletion of every 5th word, and is used as a measure of reading level. Individual differences are stressed in the latter, and ignored in the psycholinguistic experiments. Shannon (1950) gives a rough estimate of word redundancy as 54%.

The various studies of orders of approximation to English involve the same technique. Miller and Selfridge (1950) presented auditorially lists of words of 4 lengths and 7 orders of approximation. They found that recall increased with order of approximation up to about 5th order, and that higher orders benefitted more from longer passages. Richardson and Voss (1960) replicated the experiment with similar results. Bruce (1965) reported that he has unpublished adult data which are also similar. Salzinger, Portnoy, and Feldman (1962), used the same passages, but applied the "Cloze" technique to measure contextual dependencies in the material. They found that the number of correctly guessed words increased from order zero to order 7 and that having 6 words on either side of the blank is superior to having only 4. The order of approximation scale was shown not an equal interval scale. Connected "text" was out of line--that is, subjects were less successful in guessing omissions from a text than from a 7th order approximation. Treisman (1965) also found the same general result. In addition to Coleman's criticism of the higher order approximations used (vide infra), another possible explanation is that the authors whose texts were selected were creative writers (Joseph Conrad, not a native English talker, in Treisman's text); if they had been conventional hacks, the subjects should have guessed text best of all. Sharp (1958) also studied the effect of order of approximation with auditory presentation with the same general findings.

Wallach (1963) measured the accuracy of tachistoscopic thresholds for 6-letter words of various approximations to English for 5th grade children and found a positive relationship. Miller, Bruner, and Postman (1954) had found a similar effect with adults, using 8-letter words, but very few subjects. Although the number of letters correct increased with order of approximation, the amount of information (H) was independent of it. Tulving (1963) recalculated the information content of their stimulus material and found an even better approximation to linearity. Morton (1964 a) studied the reading of passages of various 7th-order approximations to English in adults. He found that the time for reading a passage decreased up to the 3rd order. Mean reading speed per syllable increased up to 5th order, and speed for text was best. Mean number of errors decreased to 5th order, and the eye-voice span increased up to the 8th order. The number of fixations decreased to 5th order, and the majority of these were regressions. Ohnishi (1962) measured the eye-voice span for 0, 1st, 2nd, 3rd order approximations to Japanese and text. Order of approximation was very significant, but, as with English, the amount of information was approximately constant.

Baddeley (1964) repeated the Miller, Bruner, and Postman experiment with increased exposure time because he felt their results were due not to perception but to informational limitations of immediate memory. He found a highly significant effect of order of approximation, and a slope like Miller, Bruner, and Postman's "perceptual effect." Predictability (based on the "statistical subject") correlated .80 with recall. He thought that the effect of higher orders of approximation tends to be masked because, there is less information available in the short sequence used.

Marks and Ollie (1952) criticized the Miller and Selfridge experiment for not scoring word sequence, for failure to control for practice, and for certain aspects of the material. They used improved material, and separate groups of 20 subjects each at each order of approximation. Their subjects were given increasingly long segments to repeat, in sequence, until they failed two consecutive tests. They found great differences and these increased through "text". They disagreed with the Miller and Selfridge conclusion that there is no distinction between meaning and nonsense.

Deese (1961), like Miller and Selfridge, and Sharp, found a decrease in recall after 5th order approximation (with rather sparse data). Deese pointed out that the greatest difference in recall between orders should be between 0th and 1st because 1st order lists are weighted according to frequency of occurrence and therefore must contain frequent repetitions of very common words. He attributed the frequency effect either to guessing behavior (response bias), or to the possibility that mere presentation may differentially affect the high-grequency items. He claimed that there are two factors in recall: association and reconstruction of language pattern and that the reconstruction, according to language patterns accounts for the better recall with higher orders of approximation.

Lachman and Tuttle (1965) set out to test the construction hypothesis by comparing recognition with recall, using simultaneous auditory and visual presentation. They argued that recognition would not be subject to output construction as recall is. The higher order of approximation was superior under all conditions, recognition as well as recall, which they interpreted as supporting a storage hypothesis rather than a construction hypothesis. They found no evidence for perceptual errors, and finally were led to reject the input construction hypothesis also. They concluded that higher orders of approximation are more efficiently stored. Our own data show a strong frequency effect in recognition.

Coleman (1963) considered the results of Miller and Selfridge, Sharp, and Deese incredible, and attributed their results to the fact that the grammatical constructions in higher order approximations seem far-fetched (to say the least!). He had 12 linguists rank for grammaticalness 12 sets of passages of 0th, 1st, 2nd, 3rd, 5th, and 9th orders of approximation. The curve of rated grammaticalness rose to order 5 and then dropped, as the order of approximation became higher, just as the recall scores had. The grammatical constructions became awkward and implausible, as he had claimed. He also found that the higher orders of approximation in the three criticized studies contained more syllables per word and also less frequent words. Finally, he did an experiment using passages which were matched for word frequency and syllabic length, and he also scored sequences of correctly recalled words, not just correct words regardless of order. He found that the number of words recalled in sequence increased all the way to text, and that the advantages of higher order approximations increased as recall was scored in longer sequences.

Treisman (1964) had subjects shadow messages led to one ear, while irrelevant messages were led to the other. The number of words correctly shadowed decreased with decreasing order of approximation.

Conway and Quarrington (1963) had stutterers read aloud 7-word sequences of 0th and 3rd order of approximation and text. They found both order of approximation and position in word significant, but not their interaction. In another study, Quarrington (1965) found a significant correlation between the points at which stutterers stumbled and predictability of words by normal S's.

Grammatical constraints are clearly part of the total constraint in language. Several studies have approached this problem directly. Miller, Heise, and Lichten (1951) found that words in a sentence were more intelligible in noise than were the same words in scrambled sequence. Stowe, Harris, and Hampton (1963) studied the effect of number of context words preceding the test words and found that the intelligibility increased with increasing context. They concluded that their data support the hypothesis of Miller, Heise, and Lichten that context operates to restrict the number of possible alternatives, and that number of preceding words is an adequate definition of context if taken over a large sample. They also found a virtually perfect negative correlation between average fraction correct and number of less common words (less than 50/ million T-L count) in a list of 30 sentences. It is obvious that there are several separate factors operating which need to be studied separately. Several such studies have been done, but they are not of direct relevance here.

Shepard (1963) had subjects supply all possible words to fill a blank, given 0, 1, 2, 4, 6, 10, and 40 words of context. He also used Shannon's method for estimating the uncertainty of the missing words. He found that the greater the context the fewer words were produced, and the average rate of production dropped as constraint increased. These findings fit in well with those showing the importance of restriction of message sets.

Postman and Adams (1960) compared incidental and intentional learning for 3 orders of approximation and text (using the Miller and Selfridge materials). They found both approximation and instructions highly significant effects, as well as their interaction. They proposed that the negative acceleration of the two curves with increasing order of approximation indicates that the verbatim recall of a series depends primarily on short-range dependencies. Their materials are not adequate for a generalization of this scope. They also found that the mean number of errors increased with order of approximation, which may be related to our false alarm rate.

Fried (1963) read passages to 7 groups of high school students, 15 passages at each of 7 approximations to English. Recall scores for individual words showed rapid improvement up to 4th order, as Miller and Selfridge found. Recall for word groups was similar to that for individual words up to 8th order, when a sudden effect of grouping occurred. Length of passage appeared not to be a factor for lengths of 20 to 100 words.

Deese and Kaufman (1957) tested 40 S's with the Miller and Selfridge lists, using 7 orders of approximation and text. There was the usual increase in recall as order of approximation increased; the zero-order curves show a recency effect, whereas the 7th order, and especially text, show the strong primacy effect.

Michon (1964) studied the recall of groups of 12 letters in units of various sizes for 0th, 1st and 2nd order approximations to Dutch. He found that the higher order approximations were more profitable for the longer units.

Imae and Takeuchi (1959) reported significant effects of order of approximation to Japanese for intelligibility, immediate memory span, recall, and eye-voice span. Their data on recall of words are very similar to those of Miller and Selfridge (1950).

Ohnishi (1960) investigated the effect of order of approximation to Japanese upon tachistoscopic thresholds and upon recall. In both, order of approximation was highly significant.

Studies of Children's Language

Finally we turn to the literature on learning of language materials by children. We are not here concerned with the vast literature on reading. The fairly substantial literature on association tendencies is deemed of only indirect relevance to the problem in the present state of knowledge. Although there has recently been increasing interest in child language, there is not a great deal that applies directly to our problem --the usual paired associates or serial learning tasks do not (but see Keppel, 1964). Much of the research has had to do with development of grammar (cf. Braine, 1963; Bellugi and Brown, 1964, Menyuk, 1963a and b, 1964a and b, Kean and Yamamoto, 1965), or usage of word classes (Brown and Berko, 1960; Ervin, 1961; Entwisle, Forsyth, and Muuss, 1964), or association norms (Palermo, 1963). Strickland (1962) analyzed, in a large sample of natural speech, the grammatical forms used by children of several age levels and compared this distrubution to one obtained from children's readers at the same levels. Her conclusion was that there was a wide discrepancy between children's natural language and the language they are given to read, and that there should be a more orderly introduction of grammatical patterns familiar to the child. She did not find any great differences between First and Fifth Grade speech in terms of grammatical patterns, but there were some differences related to intelligence and other like variables.

Ruddell (1965)found that use of syntactic patterns similar to those commonly used in Fourth Grade oral language significantly affected reading comprehension.

Loban (1961, 1963) followed the development of a number of language skills in children from kindergarten through Sixth Grade, using the same syntactic framework that Strickland used. He found flexibility within the basic sentence patterns the best measure of the effectiveness of language, not the basic patterns themselves, at this level. The high ability group in oral language was also the high reading ability group.

Templin (1957) and Harrell (1957) also analyzed children's speech. Templin found that 'sentence' length increased with age (3 - 8 yrs.) and so did grammatical complexity. There were fewer incomplete sentences (as Loban also found), and an increase in coordination and subordination at higher age levels. After 3 years of age the parts of speech used showed little change. She emphasized that the language of children is functioning very much like adult language. Harrell compared spoken and written language in Fourth, Sixth, Eighth, and Tenth Graders. He found results very similar to those of Templin, and Loban--"mazes" decrease, subordination increases. Davis (1937) studying oral responses of 5-to-9-year olds also found increase of sentence complexity with age. Strickland, Loban, Templin, Davis and Harrell all use a phonological unit, not a syntactic one, to define an utterance, as did we.

It is surprising to find that there is so little experimental material on children's management of language. What work there is is overwhelmingly visual, even with young children who are not reading well. White (1963) calls for more information about how children handle auditory and tactual information, stressing the differences between auditory and visual stimuli. Carroll (1964) is likewise concerned with the paucity of information about children's processing of aural language.

There are only a few observations which pertain directly to redundancy in children's speech. One, of course, is size of vocabulary, but even in the very young, the number of words in the active vocabulary is rather large, and may contain virtually any word in the native language (Rinsland, 1945, p. 20). Gewirtz (1948) found that the older (6:7 vs. 5.0 yrs.) children in his small group were more likely to use the same words repeatedly in free expression. Di Vesta (1964) found some evidence of greater variability of modifier type in 2nd graders than in older elementary school children. Palermo (1963) found similar evidence. Voegelin and Adams (1934) found greater variability of consonant phonemes in very young children. Entwistle, Forsyth, and Muuss (1964) reported a rapid increase in commonality of word association responses over the 5 to 10 year age range. One could guess that language redundancy might increase and then decrease, as stereotyped phrases became more common.

Kluppel (1962) studied visual serial learning of trigrams of high and low frequency (as determined by children's own completion of high frequency digrams) in Second, Fourth, and Sixth Graders. The high frequency trigrams were learned significantly faster. Bogartz and Carterette (1963) studied children's learning of random vs. redundant strings of letters or digits. They found that redundant strings were learned faster than random, but as adult data have also shown, less information is acquired (Miller, 1958). They noted, too, that certain terminal elements occurred in responses according to their frequency in stimulus strings even when few or no strings had been learned completely. Wallach (see above, 1963) found accuracy of tachistoscopic recognition to be positively related to order of approximation to English for Fifth Grade children. Bruce (1965) studied the performance of school children in the Miller and Selfridge type of experiment, using 0th to 7th order approximations to English. He found similar results, although lower scores, but there were wide individual differences for children, not found in adults (cf. our ROC curves for 1st graders and adults). Wicklund, Palermo, and Jenkins (1964) also found differences between children and adults in the sensitivity of paired associate learning to free-associative strength of response items.

Rice and Di Vesta (1965) found that the basis for generalization from words paired with nonsense syllables during learning changed from Third Grade to Fifth, Seventh, and college. The younger subjects generalized only to homonyms in both recognition and relearning; with increasing age, generalization to synonyms became more apparent, with college students generalizing equally to homonyms, synonyms, and antonyms. Since the presentation was visual, this study lends some weight to the notion that there is a strong auditory component in written language at all levels, and indicates that it may be considerably stronger in younger subjects.

Morin and Forrin (1965) found verbal reaction-times slower for First than for Third Graders. They also found that mean reaction-time increased for both groups with increasing stimulus information only with naming of simple shapes, not for naming digits. The same results were found with adults. They believe that their results support the hypothesis that the slope of the function relating reaction-time to stimulus uncertainty decreases with the habit strength of the S-R associations.

Rossi and Rossi (1965) studied 7 groups of 30 children each, one in each half-year of age between 2:0 and 5:0. Half the subjects at each age level were presented with 12 stimulus words auditorially, half were shown pictures as E read the names to them. Then they were given 2 minutes for recall. There were 3 trials using the same words in randomized order. All groups clustered significantly and clustering increased significantly over trials. They concluded that children can cluster as soon as they can talk. Indeed the use of language appears to imply just such concept-forming ability, but to our knowledge, it has not been shown before in children of this age.

Visual vs. Auditory Processing of Information

The work on the comparability of auditory and visual processing of verbal material is difficult to evaluate because of differences in the two which are often overlooked. In particular, auditory presentation is often confounded with visual by requiring written responses or vice versa, by not distinguishing letters from phonemes, and by applying visual units to auditory material. It is also probable that, although there is transfer from auditory to written language, some units are more familiar in one modality, and others in the other. There is some indication that visual and auditory language components may operate in different ways (Dale, 1964; Williams and Derks, 1963; Postman and Rosenzweig, 1956). The literature addressed to the problem of whether learning proceeds faster with auditory, visual, or a combination will not be reviewed. In general there is insufficient attention paid to a number of important parameters, and the findings are of little general significance.

Forrest (1957) presented dissyllabic nonsense words auditorially to his subjects, at frequencies of 0, 5, 25, and 200 repetitions. He then measured the visual tachistoscopic thresholds. The visual thresholds decreased significantly with each rise in number of auditory repetitions. This appears to answer the question of whether spoken language frequency affects visual-verbal information processing. Cf. our finding of a visual frequency effect with First Graders.

Carterette and Cole (1963) compared ROC curves for audition (signal in noise) and vision (tachistoscopic exposure) for a known message set and found them very similar.

Budoff and Quinlan (1964a) compared auditory and visual learning in Second Graders using material reasonably well controlled for frequency (i.e., all of it high, both visually and auditorially). They found that the aural material was learned much faster than the visual, but point out the need for a longitudinal comparison. Budoff and Quinlan (1964b) also tested paired associate learning of primer words in 28 average and 28 retarded readers in Second Grade, using visual and auditory presentation. Both groups learned more rapidly with aural presentation, and there was no interaction between reading level and modality. Lockard and Sidowsky (1961) found auditory presentation worse for Fourth Graders, but they used a very unnatural kind of auditory stimulus, speaking letters, their groups were small and the task demands exhausting for children.

In terms of effective teaching it is important to know which method of presentation is more effective at each grade level. McNeil and Keislar (1963), using a large number of 5-year-olds in an automated reading program, found the orally responding group to have learned more than the non-orally responding group. Both groups pressed a button to insure attention, and it is not entirely clear that the extra response on the part of the oral group may not have confounded the situation. However, W. N. Smith (1965) found (with adults), that speaking a word which matched a visually presented word significantly increased the accuracy of visual recognition, whereas speaking a mismatched word was not significantly different from the silent condition. Similarly, Peterson and Peterson (1959, Experiment II) in studying auditory short-term retention, had half their subjects repeat the stimulus syllable aloud and had the other half keep silent before the filled delay period. The vocal group improved with repetition at each of the recall intervals. It may be the auditory component which is improving the performance.

Peisach (1965) applied the "Cloze" technique (5th order approximation) to speech samples, and then presented the material both visually and auditorially to First and Fifth Graders. The auditory presentation was more difficult for speech of both teachers and peers. This should be related to our finding of essentially identical frequency distributions of phonemes, and identical sequential constraints on them for First Graders and adults.

Tulving and Lindsay (1965) found visual processing of information consistently superior to auditory for adults in absolute judgment experiments.

Imae and Takeuchi (1959) found no difference for syllable recall between auditory and visual presentation in adults for various orders of approximation to Japanese. Murdock (1960) found no differences in recall between auditory and visual presentation for a list of 30 very common words for which there were no homophones. It may be that their extreme frequency is the important factor here.

Henneman (1952) used visual and auditory presentations of prose passages with background noise to 3 groups of 40 subjects each. The control group had no distracting task, the 2nd group had a distracting visual task, and the 3rd had a distracting non-visual task. For the control group, visual presentation was better, but for both the distraction groups, the auditory presentation was better. He concluded that when attention is divided, aural messages are more intelligible than visual. This experiment may have more important implications for the school learning situation and for reading than any of the others because of the virtual omnipresence of distracting stimuli in school.

Methods of Testing

Although recognition and recall are very highly correlated, it is of considerable interest to note that Postman and Schneider (1951) found recognition to be more sensitive to language frequency then recall. Reading is dependent upon recognition, and our own experimental work involves recognition, but much of the evidence for the effectiveness of frequency in learning is based upon recall procedures. It might be expected then that frequency may be even more important than already indicated if sequential recognition techniques are employed. For a discussion of some of the problems involved in verbal learning experiments see Conrad, (1965).

One difficulty with much of this work with children is the difficulty they have in learning paired associate or serial lists. Jensen and Rohwer (1965) studied serial and paired-associate learning in children 5, 7, 11, 13, 15, and 17 years of age with and without verbal mediators. They found serial learning was little affected by mediation, and uncorrelated with age after 8 years. In contrast, paired-associate learning was markedly affected by mediation and strikingly correlated with age. Since there is also evidence that single lists are usually idiosyncratic, it is important to find a method for studying the learning of verbal materials which permits of many items, and does not tax the memory or attention span of young children too much. Atkinson, Hansen, and Bernback (1964) devised a short-term memory task for nursery school children, which proved very effective. The data show decreasing proportion of correct first choices as a function of the number of intervening items, but no primacy effect; a primacy effect was, however, obtained with 10-year olds and college students. Although it was not a verbal task, this finding may have some implications for language processing.

Deese and Kaufman (1957) compared the shape of the serial learning curve for free oral recall of lists of words and prose passages, both of which were presented aurally at the rate of one word per second. For lists there was a major recency effect, whereas for prose passages there was a larger primacy effect, indicating the influence of sequential ordering.

Epstein (1962) presented material visually, and found that both structured and unstructured material showed a large recency effect when presented in sentence-like form, but when presented in serial form in a memory drum, both kinds of material fell into a typical serial learning curve form, with primacy an important factor. These results do not agree with those of Deese and Kaufman.

Hansen (1965) compared 5-year olds and 10-year olds on the Atkinson, Hansen, and Bernback task and found a significant difference for age, although both groups showed largely a recency effect. But changing the presentation rate changed the shape of the serial curve; rapid rate (1 per sec.) improved the recall of early items (i.e., enhanced the primacy effect), whereas a slow rate (3 sec. per item) improved the recall of later items (i.e., enhanced the recency effect). Since the comprehension of language requires sequential ordering, these findings have some implications for rate of speaking and rate of reading, but the whole problem of ordering in memory requires more thorough investigation. Horowitz (1961), for example, has found that low inter-item similarity facilitates ordering (cf. Postman, Turnage, and Silverstein, 1964). This should be considered in conjunction with our finding of distinctiveness of non-words in recognition.

False Recognition

There is some evidence that, although verbal units of high frequency are more easily recognized and learned, they are also more easily falsely recognized and produce more intra-list inhibition. Gibson, Bishop, Schiff, and Smith (see above, 1964) found their meaningful trigrams to be more often falsely recognized than their pronunciable trigrams. Rosenzweig and Postman's data (1957) suggest that the words of higher frequency produced more interference in learning than those of low frequency. Underwood and Postman (1960) claimed that their lists of high frequency words were not learned any faster than those of low frequency because of greater intra-list interference, but their materials are so poor, that it is impossible to make a judgment. Lloyd (1964) also stated that high frequency words evoke more interference and thus have less advantage over low frequency words at high storage loads, but again his materials were probably not adequate to the task. In studying experimentally manipulated frequency, Zajonc and Niewenhuyse (see above, 1964) found false recognition positively and very significantly related to training frequency.

Underwood (1965) found false recognition related to the frequency with which an implicit associative response was presumably evoked by a number of different stimulus words. These findings are of course related to those from the tachistoscopic studies of the effect of both manipulated and natural language frequency, where incorrect responses tend to be units of greater frequency (cf. McGinnies, Comer, and Lacey (1952), Savin (1963), Goldiamond and Hawkins (1958)), and should be considered in conjunction with our experimental data which show that low frequency words are more often falsely recognized than non-words (i.e., zero frequency of occurrence).

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4. Procedures

A. Statistical Studies

1. Sources of Material

a. Spoken Language

Because of the requirements which we set for the samples of spoken language, particularly those of sample size, unrestricted vocaublary, and lack of other restraints, it was necessary to collect a proper sample. The few samples of spoken language which have been collected are limited by the difficulties mentioned, and more particularly by poor fidelity of recording--a very important point for phonetic analysis--and are ordinarily unavailable for reanalysis. Of the three modern analyses of spoken English which concern themselves with phonology and analysis of language constraints, Denes' paper, Analysis of Spoken English (1963), is only an analysis of two phonetic readers, Baddeley, Conrad, and Thomson's paper (1960), is based upon written British radio dialogue, and Hultzén, Allen, and Miron's monograph (1964), is based upon conversation from American plays. For our analysis it was desired that the sample should be sufficiently large so that any descriptive measure (with the exception of word counts, which require a vast and expensive sample) would be stable and representative. Likewise, it was important to obtain adequate language samples at several levels of language competency. The two reasonable extremes were thought to be an adult sample and a First Grade (approximately 6-year olds) sample, the latter consisting of children who were just beginning to learn to read and thus have virtually no acquaintance with visual language. To have dealt with younger children would have entailed great difficulties in terms of rapport, time, and representativeness. The other two samples chosen were Third and Fifth Graders, judged to be at such positions on the growth curve as to shed some light on the development of language to adult status. The adult sample was similar to the child samples in community, national and regional origin, and socio-economic status. It was obtained from junior college classes at a city college, in California.

We arranged to use children from two different schools to reduce possible biases of unsuspected sorts. Both schools had children drawn largely from the middle socio-economic level. The investigation of the effect of socio-economic status on language development is an important one, but not the subject under investigation here. Moreover it also requires a norm. It was just this norm for studies of language development of all sorts that we wished to record. We used all children in a grade who were present when called and were not excused by reason of foreign language background, marked non-California dialect, or speech impediments. Since regions of the country differ in the phonemes used in speech, it was judged more in keeping with the aims of the study to include only one type of regional speech, which happened to be Southern Californian. Several ways of arranging a situation in which natural speech would occur were tried. First, an attempt was made to record unrestricted free speech of children among their peers in the lunchroom or on the playground. This was a complete failure acoustically because the noise exceeded the signal at all times. An attempt to record discussions in the classroom also failed because of excessive noise and poor flow of speech. Next, recordings of speech were made while individual children responded to requests to make up a story about pictures shown them. The speech was impoverished in grammatical constructions, vocabulary, rate, and even phonemes. The speech of a child when responding to requests to tell about summer vacation or what he would do during the next vacation likewise was not normal speech. Next, Strickland's method (1962) was tried. This required "props"--a group of objects on a table--and a small group (3 or 4) of children seated around it. The children were asked by the adult moderator to talk about the objects. The response was better in this situation, but even here there appeared to be restriction both of vocabulary, and grammatical forms. The normal flow of speech became halting. Finally we tried a simple social situation. Three children were seated around a small table with a young, friendly adult. The adult greeted the children by name, told them she wanted to find out what children in their grade were interested in, and asked them to talk to each other about anything they wanted to talk about. Some groups required somewhat more encouragement; if so, the adult asked a question or two: "What do you do after school?," or "How many in your family?" Thereafter she said nothing. After the initial warm-up period, which was always discarded for the transcription, the speech appeared to be children's normal speech. It was rapid; there were interruptions; it covered every conceivable topic; it was full of slang and noise words; there was give-and-take. This, then, was the situation in which all the child speech samples were recorded.

For the adults the situation was structured differently. The participants were from elementary psychology classes, so their knowledge of psychological jargon was flattered. They were told that the experiment was one in small group process and that the situation was to be completely non-directive. Then they were introduced by first names and told they were at a party. The experimenter excused himself (psychologically) to get the snacks. Again groups of three were always used. Most of the adults did not know each other, whereas in the children's group, they did. The 3-person interaction proved as useful for adults as for children, and the language produced was judged to be normal, everyday conversation, as rapid, slangy, and diverse as any in an unrecorded situation.

The second major problem concerned the quality of the recording. If phoneticians were to be able to transcribe the material with any reliability, the recording had to be very good - better than any speech recordings we had heard. To this end we assembled the following high fidelity components: (1) Ampex 1260 4-track stereophonic magnetic tape recorder and (2) 2 Altec-Lansing Model M-20 microphone systems. The microphones were placed 2 feet apart, and about 8 feet from farthest talker. New Scotch (Minnesota Manufacturing and Mining Company) 1.5 mil acetate magnetic tape was used. Recording was at 7.5 inches per second and each microphone fed a separate channel. Thus, only two of the four tracks were used, giving the maximum possible channel separation, since an unused channel separated the two which were used. The cross-talk rejection ratio in the middle frequencies was much greater than 60 db, far more that adequate for our purposes. The recordings were made in the best available room at the three schools. Test tapes were made to disclose the acoustic properties of the room. Where necessary, one section of the room was draped with cloth, felt was applied to chair and table legs, microphones were adjusted and insulated. The gain of amplifiers was checked at every tape change. The microphones were always concealed from the elementary school children. To the best of our knowledge, their presence was not suspected. For the case of young adults, the microphones were in plain sight, since they would have deduced their presence in any case. After the brief warm-up period, they lost themselves in conversation and paid no further attention to the presence of the microphones or the experimenter. In fact, it was often hard to get them to stop at the end of the period.

Since the aim was to collect a sample as representative as possible of natural language, we attempted to include as many individuals, and as many groups as possible, in order to reduce the effect of idiosyncracies of vocabulary, topic, sentence construction, pronunciation, and various aspects peculiar to spoken language. However, it was also important to allow sufficient time for each group to warm up and then become thoroughly engrossed in conversation, for otherwise many aspects of oral language suffer.

We have shown (Jones and Carterette, 1963) that at least 6,000 words are necessary for stable statistical results, so the goal was set at 10,000 words per level. It was felt that more than this would require too much time for phonemic transcription, which is very slow. Well over 10,000 words per level were actually transcribed, but more material than that was collected and remains untranscribed. The number of groups and individuals represented in this analysis is:

Level	No. of Groups	No. of Individuals
1	18	54
3	16	48
5	16	48
Adults	8	24

The reason for the discrepancy in number of groups and individuals is the size of the sample required at each level. First graders did more giggling, interrupting, and drowning each other out, so less usable material resulted per unit time. The total number of characters transcribed is given in the following table.

is given in the following table.

Level	Total Number of Units				Lexical Words
	Letters		Phonemes		
	A*	B*	A*	B*	
1	94,767	72,742	66,179	58,653	20,030
3	101,285	78,065	70,842	63,029	21,368
5	131,274	101,618	90,741	80,970	27,072
Adult	78,580	61,269	54,478	48,708	15,694

b. Written Language

The sources of written language suitable for the various grades was sought first in standard reading text books. Readers of two widely used series were chosen as representative of material of this sort; First, Third, and Fifth Readers were used in both series. The series were the Ginn Readers, and the Sheldon Basic Readers (Allyn and Bacon). The references appear in Appendix IV-7. In addition, the Second Reader in the Ginn series was analyzed, after it appeared that the step between First and Third Readers was very large. All material in a given section was used with the exception of foreign words and poetry. Abbreviations were spelled out according to a rule (e.g., Mr. = Mister). Any story containing a large number of foreign words was omitted. The only punctuation marks used were word and sentence mark. The exact rules are given in Appendix IV-1.

Next, material which children like to read was sought. Wilson's Children's Catalog (West and Schor, 1961) was used as a guide because of the large number and wide distribution of the judges making the ratings. These books are rated by children's librarians from all over the country and by specialists in children's literature as books they could not do without. Each rating is accompanied by a concensus of proper grade level. We chose at random from among those books rated in the top one-ninth and assigned to Kindergarten through Second or Third Grade as our Level 1, those assigned to grade 2 or 3 through 5 as our Level 3, and those assigned to grades 4-6 as our Level 5. At a single level we used all or part of three or four separate books, drawing equally from them to reduce the effects of idiosyncratic language, aiming at approximately 10,000-word samples. Although there is undoubtedly some adult bias in these ratings due to pedagogical urges, the ratings are also dependent upon circulation and enjoyment in "story hours." It is difficult to believe that a book which is unpopular with children could remain in the list year after year, regardless of adult bias. At least these ratings have the advantage of representing a national sample and a large one. For the books used, see Appendix IV-7.

Written material on the adult level had previously been analyzed by Newman and Waugh (1960). Their calculations were used for average adult text (William James sample) and difficult adult text (Atlantic Monthly sample[1]), but for the easy adult text (the King James' Bible), we punched the same passage and computed our own statistics. Figures for the Russian Bible were also taken from Newman and Waugh.

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* Column A refers to total number of characters, B refers to this total with word marks and sentence marks removed.

2. Transcription Procedures

a. Written Language

Since ordinary alphabetic characters are acceptable to the FORTRAN program to be used in the statistical analysis, transcription of the written material consisted in key-punching directly from the text, according to the rules given in Appendix IV-1. Once punched, these were proof-read by two people, corrections made; and the corrections proofed. The original key-puncher did not proof her own work alone.

b. Spoken Language

Transcription of the spoken language was very much more difficult and time-consuming. Each tape was first transcribed by a typist, listening with stereo earphones on a research-quality playback system (Ampex Model 350-2, two channel magnetic tape-recorder). This often required many iterations. The instructions were to include all consecutive material, but if some part was incomprehensible to omit the entire utterance. Similarly, if some person was interrupted and did not pick up the thread of his utterance, the whole utterance was to be omitted, but if he did, then the interruption was to be omitted. The purpose of these rules was to preserve the continuous and sequentially-dependent structure of speech.

Ordinary lexical words were used in these letter transcriptions, to make them comparable with the written material; i.e., words were spelled properly and word marks occurred where they would normally occur in written material. However, normalized spellings were constructed for idiosyncratic words (e.g., "guy," used by many of the children as an exclamation), "noise" words (cf. Strickland) like "er," "uh," and the like.

The placement of sentence marks became a very difficult problem. Since a good deal of the material was agrammatical, the use of a grammatical criterion was deemed inappropriate, since it would conceal any unusual implications of the data. An attempt was made to use tentative pause and final pause, but the two phoneticians could not assign the first of these reliably, so it was abandoned. The terminal juncture was placed by the phoneticians and used whenever an utterance was terminated by a change of speaker or when there was a clear pause of a type the phoneticians were willing to call terminal, judging largely by intonation contours and appreciable silence. The reliability was not high for this aspect of the transcription. Detailed transcription rules are given in Appendix IV-2.

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[1] An error in their calculation of C_{11} was discovered and is presented correctly here.

The second step was to have the letter transcriptions checked by a research assistant. This always resulted in many changes.

Next the phoneticians took over. When we could get them, there were two working. Because of the volume of material, it was not feasible to have them both transcribe all the text independently. Instead we had to be content with occasional reliability checks together with subsequent ironing out of discrepancies. The tapes transcribed by each phonetician are classified in Appendix IV-4.

Two formal reliability checks were made. The number of disagreements in a passage were counted and this number was divided by the total number of phonemes in the passage. In the first instance there was 6% discrepancy in 2300 phonemes transcribed. In subsequent discussion, agreement was reached. This involved listening together to the taped passage and evolving new rules for transcription. Examples of these are: (1) Don't use schwa if you can hear the quality of the vowel, (2) if the sound is genuinely between a "t" and a "d," use the one which is normal for the word. A second check revealed a still greater discrepancy, 16% (1800 phonemes). Much of this was due to insistence by the authors that the transcription be as phonetic as possible within the bounds of the phonemic alphabet. Since the phoneticians were not used to this procedure, and also had used different systems in the past, some learning was necessary. The intent, with which everyone concurred, was to represent all the variations possible. There were three very good reasons for not attempting a phonetic transcription: (1) The programming would have been more difficult, (2) the transcriptions would have been very much less reliable, and (3) the import of speech seems to be much better rendered by the phonemic transcription since this is presumably based upon the contrastive features of the language (Daniel Jones, 1962). The phonetic use of the phonemic alphabet with children was intended to permit discovery of lesser redundancy in young children due to inconsistency in pronunciation, if this existed. As an aside we should like to point out that apparently most so-called phonemic transcriptions of an individual's speech that appear in the linguistic literature are really pseudophonetic transcriptions like ours. That is, a standard phonemic alphabet is used to represent the phonetic character of the speech, but the contrastive analysis necessary to establish his phonemic system is never undertaken. We shall hereafter refer to our analysis as phonemic, with the understanding that it is not technically a fully phonemic one.

The phoneticians placed "word marks" only where there were brief pauses. Instructions were to not make printed words a guide, but to indicate only natural breaks in the flow of speech. Sentence marks were likewise placed at natural terminal pauses, defined not by grammar, but by: (a) change of speaker, or (2) a terminal intonation contour plus a substantial pause. The purpose of these rules was to permit generation of hypotheses about the natural units of language, since it became immediately obvious upon listening to the tapes that the language was quite different from linguistically ideal or written language. The 41-character alphabet used is presented in Appendix IV-3. There are 39 phonemes, 14 vowel and 25 consonant phonemes, plus word mark and sentence mark.

The problems of reliability of transcription were dealt with as effectively as possible under the constraints of time and availability of phoneticians. Phonetics is not an area in which Linguistics students in America are highly trained. It is therefore difficult to hire phoneticians with any but minimum experience. The turnover was likewise high, with long periods of vacancies and retraining. Four phoneticians participated in the final transcriptions and all were interested enough in the project to give it more than mere duty required. There was free interchange and discussion between the members of each pair and some interchange across pairs.

3. Statistical Methods

A program for computing the sequential constraints of chains of symbols (i.e., letters, phonemes, words, grammatical forms) was written for the IBM 7094 computer.* The program computed measures of information and redundancy on a printed "language" each of whose symbols was represented as an arbitrary symbol of the FORTRAN Keyboard. Hence a maximum of 48 characters was allowed. The measure of information, an estimate of the Shannon-Wiener measure of selective information (Shannon, 1951), was printed out along with an adjustment for bias due to sample size (Miller and Madow, 1954).

Contingency tables were constructed showing the number of times each character was followed by every other character, both immediately and at lags of 2, 3, ..., 11, 29, 59, and 119. From these contingency tables, H_v the information associated with this *a*-state stationary Markov chain, was computed from

$$H_v = -\sum_{ij} P(i)\, P_{ij} \log_2 P_{ij}, \qquad (1)$$

where $P(i)$ is the absolute probability of being in state i and P_{ij} is the stationary transition probability of going to state j on the $(n+1)$-th trial after being in state i on the n-th. The relative sequential constraint on the second of a pair of characters when it is the n-th member of a sequence n characters long (in which the first character of the pair is the first member of the sequence) is defined as C_n and is given by

$$C_n = \frac{\sum_{k=0}^{n-1} H_k(1:2)}{H(1)} . \qquad (2)$$

The contingent uncertainty $H_k(1:2)$ is defined by

$$H_k(1:2) = H(1) - H_v(k), \qquad (3)$$

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* A copy of the program can be obtained from the authors upon request.

where the first term of the right side of the equation is the uncertainty without sequential dependency, i.e., the average amount of information in each letter,

$$H(1) = -\sum_{i=1}^{i=a} P(i)\,\log_2 P(i). \tag{4}$$

$P(i)$ is the probability of the i-th symbol's occurrence, and a is the number of symbols in the alphabet. $H_v(k)$ is the Markovian information at lag k. It is formally identical with Equation (1). The index k specifies the forward distance of the transition from symbol i to symbol j. Thus, C_2 gives the relative sequential constraint on the second of a pair of characters in which the second character is contiguous to the first; C_3 gives the relative sequential constraint on the second of a pair in which the second is separated from the first by one character; and so on. Equation (2) makes the subscript of C (that is, n) equal to the lag plus one. We used k's of 1, 2, ..., 11, 29, 59, and 119, which yielded the constraints between all pairs of characters in which the second was at the designated step to the right of the first. For a discussion of the restrictions on these computations, see Garner (1962, p. 213 ff) and Edwards (1962). Finally, mean word-length and mean sentence-length for each text were calculated.*

An estimate, H''', of $\hat{H}$ unbiased to terms of order $\frac{1}{n^2}$, (Miller and Madow, 1954), was used:

$$H''' = \hat{H} + \log_2 e \left[\frac{a-1}{2n} - \frac{1}{12n^2} + \frac{1}{12n^2}\sum_{i=1}^{a}\frac{1}{P(i)}\right] \tag{5}$$

where a is the alphabet size, and n is the sequence length in symbols. $\hat{H}$ is, of course, the estimate of the theoretical quantity H, and is found from $\hat{P}(i) = \frac{f_i}{n}$ and $\hat{P}_{ij} = \frac{f_{ij}}{n}$. The quantity f_i refers to the frequency of being in state i on trial s, whereas f_{ij} refers to the frequency of transitions from state i on trial s to state j on trial $(s + 1)$. Both estimates H''' and $\hat{H}$ were computed for each P_{ij} and $P(i)$. Apparently the sample sizes used were sufficiently large to give stability, for $\hat{H}$ and H''' differed by only a few thousandths of a bit at most.

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* This schematic development and the equations given are different from those of our earlier papers (Carterette and Jones, 1963, Jones and Carterette, 1963; see also Newman and Waugh, 1960). We are dealing specifically with pairwise sequences of symbols that form a Markov chain and not, as our earlier equations wrongly implied, with pairs formed by sampling from a bivariate distribution. However, the earlier equations and those of the present paper lead to identical numerical results. For an interesting discussion of the different assumptions underlying the two sets of equations, see Binder and Wolin (1964).

No attempt has been made to make statistical tests between the various redundancy functions, e.g., whether the redundancy functions for First and Third Grade natural speech are different.* In view of the correlations among the various constraint measures, it is not clear how they should be made. We point out, however, that the functions are very stable, and there is but one instance of a crossing of two functions which were in any case very similar to begin with.

Where relative frequencies are concerned the statistical assessment has been by means of the Pearson product-moment correlation coefficient, $\underline{r}$.

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* For a basic discussion of testing hypotheses based on information measures, see S. Kullback (1959).

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B. Experimental Studies

1. Pilot Studies

A number of techniques for studying the influence of language redundancy upon verbal learning were investigated to determine their suitability for use with young children and for auditory presentation, since most studies of verbal learning have been done with visual materials, using adult subjects. We were seeking a method with which the word frequency effect often found in adults would show up strongly, and which would also have some resemblance to the task of reading.

(1) Method of Pair Associates

The method of pair associates was not tested because it is very difficult for young children. There are both stimulus and response variables to account for, and the number of items tested would be so small that there could be no guarantee of representativeness.

(2) Serial Learning

The next most obvious method is serial learning. Three variations of this were tried. We first tried 6-item lists of trigrams which are also words, using the extreme groups: First and Fifth Graders, and visual presentation only. The frequency was trigram frequency as determined from the Pratt count (1939), and the child responded by saying the word. For the First Graders prompting was necessary, thus confounding the auditory and visual modalities and rendering the task useless at this level. These results are shown in Table 18

Next we tried serial lists of high, medium, and low freuency words, six items in length, with a small sample of First, Third, and Fifth Graders. The words were three-letter words, the frequency of which was determined from the Thorndike-Lorge word count (1944). They were presented visually by means of a Hunter card-master, or auditorially by means of high-fidelity magnetic tape via earphones. The lists were six syllables long, two of high, two of medium, and two of low frequency. Four different lists were used; one randomly assigned to each subject. The items were exposed for 4 sec., with a 2 sec., inter-item delay for the visual experiment; 6 seconds elapsed between the beginning of one item and the beginning of the next in the auditory experiment. The subject attempted to say the letters before they were presented. The list was repeated until he could anticipate each word in proper sequence once through correctly plus one more trial for immediate recall. Since number recalled is not a sensitive measure, the data are presented in terms of average trials to learn for each of the frequency categories. The data are shown in Table 19. Without resort to statistics, it can be seen that there is no obvious frequency effect in either visual or auditory presentation at any level. Four additional First Graders could not learn the visual task. Response by letter was used because the First Graders could not be presumed to be able to read, but it destroyed the effect of the unit frequency, as might be expected. The auditory task was much easier than the visual task at all levels. This is an interesting finding, because little is known about the relative ease of learning visual and auditory materials at various ages, yet this is a very important question in planning strategies for classroom teaching at all levels.

Finally, serial lists were used with adults to see whether the word frequency effect in adults could be demonstrated by us in this task. Lists 9 items in length were constructed of trigrams which are words. The criteria were: high - above 50 in Pratt trigram count; medium - Pratt count of 10, low - Pratt count of 1 or as low as practicable. The Thorndike-Lorge word count was also consulted, in order to eliminate any words having a high trigram but low word count or vice versa. Phonemic digrams and proper names were eliminated and every effort was made to limit obvious patterning in vowels or consonants within a list[1].

The same techniques were used to present the visual and auditory stimuli as in the child experiments. The visual apparatus, the Hunter Card-Master proved quite unsuited to the task, and a good many subjects, both child and adult, were lost because of apparatus failure. In addition, it is cumbersome, noisy, distracting to the subject, and imprecise in timing exposure and interval.

Eight adult subjects were run with auditory presentation and 8 with visual. Each subject learned 3 lists, assigned at random. The results are presented in Table 20.

There is no visual frequency effect, so the task is not suitable, and was not further pursued. There is, however, an interesting finding: the auditory task is much harder than the visual task ($p< .01$), whereas the reverse was true at all levels and all frequencies for children. It may be that the difference in the response required accounts for some of this. In view of the immediate applicability of such a finding, and the confirmatory evidence from Budoff and Quinlan, it should be pursued.

(3) Short-term Memory

The next task to be tried was short-term retention (Peterson, Saltzman, Hillner, and Land, 1962). In this technique, a series of words of high, medium, and low frequency (Thorndike-Lorge count) were paired with single digits to minimize response learning. Each list was 13 to 15 items long and contained high, medium, and low frequency words at random, with tests for retention of the paired digit at 0, 3, or 6 sec., delay. There were 5 lists, each subject receiving all 5. Table 21 shows the results for First, Third, and Fifth Graders for auditory (tape via earphones) and visual (card master) presentation. A number of things are immediately apparent. First, this is a very easy task for young children, particularly in comparison with traditional methods of studying learning processes in children. They appear to enjoy it, have no trouble understanding the task, and all First Graders could do it. We have not discovered any previous use of this task with children. Secondly, it is a very different task from the visual verbal learning tasks, as evidenced by the apparent absence of a grade effect. The sample tested is small, but, if verified, these results appear to indicate that short-term memory is well-developed in First Graders, so that the slower learning shown by younger children in many verbal experiments may be due to poorer coding techniques for long-term storage. Thirdly, there is no frequency effect at any level or any delay, rendering this task useless for our purpose.

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[1] No first and last consonants in a syllable were the same; a given vowel was used no more than twice in a list; a consonant was used only once in the same position in a list.

These findings were checked with a similar series of meaningless trigrams (Pratt), using letter response. Table 22 gives the results. They confirm the findings of the first experiment in that no clear grade or frequency effect is apparent. This task, although interesting for other purposes, was abandoned at this point.

(4) Narrative Material

Next, narrative materials were tried with adults only and only auditorially. Two series of materials were prepared. First, 90 sentences were chosen at random from the Ginn Readers previously analyzed for redundancy (First, Third, and Fifth Readers). The sentences were of 3 lengths: short, 3-5 words; medium, 9-11 words; and long, 15-20 words. These were recorded in random order on stereo tape. They were then mixed with white noise at one of 5 signal-to-noise ratios and presented dichotically to the subject via earphones. Four subjects were used at each signal-to-noise ratio. Table 23 shows the results. Both the signal-to-noise ratio and the redundancy, as well as their interaction, were significant. The most powerful effect, that of noise, was expected but is one in which we were not then interested. The short sentences produced almost no errors and the long ones appeared to demand too much sheer memory, so a second similar experiment was run using uniform sentence length (9-11 words) chosen from the three free-reading choice levels previously subjected to redundancy analysis. Table 24 shows these results. There was no frequency effect at all. It was obvious (hindsight) that we had inadvertently reduced the differences in redundancy, at the same time making the sentences of equal length. A third experiment was planned to maximize the differences in redundancy, but two events intervened. First, the visual analogy of signal-to-noise ratio, tachistoscopic presentation, was not as convincing as it appeared at first blush. Second, a really promising task had come into the experimental ken. To that last pilot task, recognition, we now turn our attention.

(5) Continuous Processing for Recognition

Up to this point we had not been satisfied that any of the pilot tasks bore any very close relationship to normal processing of either visual or aural language. The only candidate with real potential was the narrative experiment and it suffered from grave difficulties in the visual sphere and also did not give promise as an analytical tool. A task, adapted from an experiment with numbers by Shepard and Teghtsoonian (1961), appeared to have all the necessary characteristics. It requires the continuous processing of sequentially-presented information for recognition after variable, filled intervals. In this respect, it closely resembles the reading or listening process. It also requires a very simple response of the subject--he merely says "old" or "new" at each presentation. This avoids all the problems of response learning and of complex decision processes. And it is equally adaptable to visual and auditory presentation.

The stimulus materials consisted of a list of 185 trigrams. Each trigram was presented for 2 seconds with 4 seconds between stimuli to allow for the subject's response. The visual presentation was by means of a Stowe memory drum. The auditory presentation was made dichotically through Permoflux PDR-600 earphones from an Ampex Model PR10 two-channel magnetic tape recorder. The subject responded orally either "old" or "new" and his response was recorded by the experimenter. He was told that old and new items would occur equally often, but he did not know how long the list was to be.

The lists were constructed of items that were both alphabetic and phonemic trigrams. The 90 key items were drawn at random with equal frequency from three pools: (1) very high-frequency words (at least 50 occurrences per million in the Thorndike-Lorge count), (2) low-frequency words (10 or fewer per million, and occurring in Webster's Third International Dictionary), and (3) non-words, which, according to Fries (1952), follow common English spelling patterns, hence should be easily pronounceable. Each key item occurred twice, the second time at one of 5 delays. Five filler items were used to provide proper delays toward the end of the list. The delays were usually 2, 4, 8, 16, or 32 items, and were assigned randomly. Two lists were usually used to control, in part, for idiosyncratic lists.

The subjects were 20 each of First, Third, and Fifth Grade children, and college students. Ten of each group were assigned to the visual experiment and ten to the auditory. The adult auditory group was the pilot group and here delays of 0-16 items were tried. Since 0 and 2-item delays were not different, all subsequent experiments were run with 2-, 4-, 8-, 16-, and 32-item delays. With the adult group, only one list was used. For all other groups list assignments were made randomly from two lists. To some extent this limits the comparability of adult and child groups, but since a larger and more refined study was under way, it did not seem advisable to re-run the adult auditory group.

Tables 25 through 28 present the results, together with the significant sources of variance. Two separate analyses of errors are necessary in every case because they are differently affected by frequency. "New" errors are failures to recognize, errors made by saying "new" to an old stimulus. "False alarms" are errors made by saying "old" to a new stimulus. It would be expected that more "new" errors would occur to low frequency words, but more false alarms to high frequency words.

For "new" errors, frequency is significant at all reading levels; for adults the low-frequency category is grouped with words both visually and auditorially, for First Graders with non-words. That is, for First

Graders, low frequency words are as hard to recognize as non-words; indeed, for them they are non-words. By Grade 3, low-frequency words are easier than non-words, as is also true for Grade 5. Fifth Graders perform like adults on the visual task, both in terms of their gross error rate and the effect of frequency upon errors. This corroborates the results of our redundancy analysis of written language, that Fifth Grade language is essentially adult and Third Grade language is approaching it. The auditory tasks are too different to permit direct comparison.

In the analysis of false alarms, frequency is not as clearly a factor, although it does occur, especially in frequency by modality interaction, with children.

Modality is a significant variable for "new" errors for adults, and enters into significant interactions for Grades 3 and 5. It also appears in all groups in some form in the false-alarm analysis. The list by modality and list by frequency interactions suggest that any detailed comparisons are probably not justified from these data. These lists suffer from the fact that the Thorndike-Lorge word counts do not represent frequencies either in adult spoken language or in child language, and, further, the confusability of phonemes is such that a perfectly good visual nonsense word like VEM piles up a very high false-alarm rate in the auditory experiment, probably because it is heard as THEM. Furthermore, several low-frequency visual words are homonyms (especially when confounded with confusability of phonemes) of high frequency words. Whereas it appears that modality is an important parameter, very much greater precision in selection of materials will be necessary to explore this further.

Analysis of the delay parameter for false-alarms for adult data was made to test the randomness of the syllable assignment, since a false-alarm is a response of "old" to a new syllable and has no delay associated with it. To our horror, delay and frequency by delay interactions were significant for both visual and auditory tasks. For the visual task a trend test showed no linear trend. For the auditory task, there was a highly significant linear component. These errors did tend to pile up in certain frequency by delay categories, and this in spite of selection according to a random number table entered randomly and separately for frequency, delay, and item. An attempt was made to solve this problem in the main experiment by using a better source for the item pool and by using multiple lists.

2. Main Experiment

The main experiment was basically very similar to the recognition experiment last described.

As before, the stimulus materials consisted of lists of 185 trigrams each of which were presented just once for 2 seconds, with a 4-second interval between stimuli to allow for the subject's response. The visual presentation was by means of a Selectroslide projector which was programmed to give the proper intervals. Each trigram was drawn on white bond in India ink and photograpned. The image was reversed and the film mounted in a 2 x 2 metal slide. The auditory presentation was made dichotically through Permoflux PDR-600 earphones from an Ampex Model FR 10 two-channel magnetic tape recorder. The trigrams were spoken in a clear male voice and the recording was done, using research quality equipment, in an anechoic chamber. The subject responded orally either "old" or "new" and his response was recorded by the experimenter. He was told that old and new items would occur equally often, but not how long the list would be, nor what the delay intervals between new and old were.

The lists were made up from items that were both alphabetic and phonemic trigrams. Since the lists used in the pilot study were unsatisfactory, Rinsland's Basic Vocabulary of Elementary School Children (1945) was taken as the new source for frequency estimates. If it does not quite reflect spoken-language frequencies, at least it represents active children's vocabulary and we found fewer blatant discrepancies with known oral usage. The items were drawn from three pools: (1) high-frequency words (occurring at least 1,000 times in Rinsland's Basic Vocabulary of Elementary School Children and 50 times in the Thorndike-Lorge count), (2) low-frequency words (occurring 10 or fewer times in the Thorndike-Lorge count, not at all in Rinsland's Basic Vocabulary, but appearing in Webster's Third International Dictionary), and (3) non-words (trigrams which, according to Fries (1952), have common English spelling patterns, but which do not appear in Webster's Third International Dictionary). For each of the 4 lists, 30 high-frequency words, 30 low-frequency words, and 30 non-words were drawn randomly from the pools. Every trigram (except for a few filler words) occurred twice, once as new and a second time as old. The trigrams were so arranged that, after the first few items, each successive item was either old or new with equal probability according to a random sequence. Either 2, 4, 8, 16 or 32 items intervened between the first and second presentations, the five levels of delay being randomly distributed throughout each list. East list was prepared for both visual and auditory presentation. The lists are presented in Appendix IV-5. The subjects were 64 elementary school children at each of three reading levels: First, Third, and Fifth Reader level (according to information provided by their teachers) and 64 adults (college students enrolled in summer session), making a total of 256. All were tested individually with a single list. Half the subjects received the visual treatment, the other half the auditory. The four lists were used with equal frequency in both modalities.

Procedure

The experimenter had been introduced to the children as a group by their classroom teacher prior to the experimental session. When a subject arrived for the experiment, he was greeted by the experimenter, shown around the room, and seated. The experimenter took a seat beside him, and read him the instructions (Appendix IV-6 a or b).

After the instructions were read and the experimenter had answered any questions concerning the procedure, the experiment began. There were no interruptions by the experimenter unless the subject wiggled excessively or failed to respond. Under these conditions the experimenter said "watch carefully" or "listen carefully" or "old or new?" On occasion the experimenter put her hand on the subject's shoulder to call his attention to the task. No information about the correctness of response was provided.

The experimenter recorded the responses on a score sheet. The presentation was always monitored, the auditory via earphones, the visual by observation. The slide holder was not sufficiently large to contain all the items, hence it was necessary to change boxes after 48 items. At this point a slightly greater delay ensued. After the experiment, the responses were transferred to IBM mark-sense cards which were later punched. Analysis of variance was done by means of a specially written FORTRAN program on the IBM 7094 computer.

Experimental Design

The design of the main recognition experiment was factorial with repeated measures on only one of the five factors. The five factors were Reading Level (R), School (S), List (L), Modality (M), and Frequency of occurrence in the natural language (F). On the last factor, (F), repeated measures were taken. The following layout will make the plan obvious.

Factor 1	Factor 2	Factor 3	Factor 4	Factor 5 (repeated)
Reading Level (R)	School (S)	List (L)	Modality (M)	Frequency (F)
1st Grade		No. 1		
3rd Grade	"C"	No. 2	Audition	High Freq. Words
5th Grade	"R"	No. 3	Vision	Low Freq. Words
Adult		No. 4		Non-Words

Thus a given subject belonged only to one grade at one school, and was tested in audition or vision, but not both, using only one of the four randomized lists. However, he was tested on all three-word frequencies, for there were 30 exemplars of each frequency in any list, or 90 different items. There were 64 subjects at each Reading Level. Half (32) of the 64 subjects in a Reading Level were drawn from each of the two schools. Of those 32 subjects, 16 were assigned to Audition and 16 to Vision. Finally, these groups of 16 subjects were each broken into smaller groups of 4, each member of which received only one of the four lists. All assignments were random.

One point must be noted. All 64 adults came from a single city college. To simplify the analysis of variance by having equal numbers in each group, half the adults were randomly assigned to Elementary School "R", the other half to Elementary School "C". (That the assignment was indeed random may be seen from Tables 33 and 34; in neither case was there a between-groups difference on the "school" factor for adults.)

The use of this particular design yields good generalizability and, because of the repeated measurements taken over frequency, affords at the same time the crucial tests of interactions among frequency, modality and reading level. The experimental design is an extension to five factors of that discussed by Winer (1962) under the heading "three-factor experiment with repeated measures (Case II)."

5. Analysis of Data and Findings

a. Written Texts

The various outputs from the computer are summarized in Tables 3 through 9. Each table shows the constraints existing between pairs of letters which are adjacent (C_2), pairs which are separated by one (C_3), etc., up to pairs separated by 9 intervening letters (C_{11}). Since all the curves appear to be asymptotic by at least C_9, the data for more distant members are not presented. $(C_{11}) \cdot (100)$ approximates the usual measure of percent redundancy, and will be used in comparisons of redundancy in texts. Also presented are: (1) H(1), which gives the average amount of selective information, in bits, contained in the single letters, (2) mean word length, (3) mean sentence length, and (4) sample size.

Date for the Ginn Series Readers are presented in Table 3 and Figures 1 and 2. H(1), the average information in the single letters, is characteristic of the language, English, not the particular sample, and will be found to be about 4.1 in all our samples, whereas for Russian text it is higher, 4.55 (Newman and Waugh, 1960). Identical H(1) implies identical distributions of frequency of letter usage. It does not imply, however, that the same letter be used with the same frequency in two texts. Table 1 shows the relative frequency for each letter for First, Third, and Fifth Grade Speech, Adult Speech, general adult text (Reza, 1961, from Dewey, 1923), and for First, Third, and Fifth Ginn Readers. Children's texts do not differ significantly from adult texts even when individual letters are compared. The correlations (Table 2) among these various sources for individual letters are remarkable; not one is below .97 and several are, for all practical purposes perfect. In terms of letter frequency distributions, English is English. It will take a more sensitive measure than this to reveal important quantitative differences in language usage. However, see Table 17 and the discussion of it, for a modification of this statement.

Data from the Allyn and Bacon Series are shown in Table 4 (see Carterette and Jones, 1965). Differences among Reader levels for C_2 are small, but as sequential constraint grows, the differences become greater. Figure 2 shows the regular nature of the growth in sequential constraint in both series of Readers. C_{11}, the index of redundancy, shows a regular decrease from First to Fifth Readers, the First Reader being most redundant (52%), the Fifth least. Since the Third Reader lay much closer to the Fifth than to the First, the Second Reader was analyzed. Its curve lies somewhat closer to the First Reader than to the Third. It is clear that there is a much larger jump from First to Third than from Third to Fifth. The two series are not sensibly different. Both First Readers are comparable in growth of sequential constraint, as are the two Third Readers and the two Fifth Readers. It is apparently possible, using certain limitations on lexicon and sentence length, to produce one text comparable to another, or by modifying these restrictions, to produce another text which will be less redundant. Judged by these particular quantitative measures, the two series of readers are comparable at each level, and show regular growth toward the adult reading level. If we can assume that the redundancy measure quantifies difficulty, then we can say that the greatest growth in reading skills comes in the first two years of reading training.

The argument that redundancy is a quantitative and reliable index of difficulty requires proof. In all cases in which there is some reason for supposing that texts differ in difficulty, there is a difference in redundancy in the proper direction. First, Third, and Fifth Readers can be presumed to differ in difficulty. In these two different series, they also differ in redundancy. Three adult texts of alleged differences in difficulty (a passage from the Bible, from William James, and from the Atlantic Monthly) computed by Newman and Waugh (1960), differ similarly in redundancy. Shakespeare, computed by Fuchs (1955) was even less redundant (29%), and is certainly difficult. And three levels of children's free-reading choices rates as suitable for three different ages likewise differ in redundancy. Redundancy, even letter redundancy, is related to difficulty of text in a way in which mean word-length and mean sentence-length, and even word frequency are not (vide infra).

In Figure 1 the Ginn Series data are plotted together with data from Newman and Waugh from adult texts of average (William James) and greater than average (Atlantic Monthly) difficulty. They used a passage from the Bible, representative of easy adult text. The points presented in the figure are from our own calculations of the same biblical passage (cf. Table 5), and differ insignificantly from theirs.

It is easily seen in Figure 1 that the Atlantic Monthly is less redundant than a Fifth Reader. The William James data are not plotted because they fall very nearly on the Fifth Reader curve. The Fifth Reader is about as redundant as average adult text, and, if this be accepted as an index of difficulty, then the average Fifth Grader is reading at an adult level, so far as language (not ideas) is concerned. Similarly, the open triangles show the plots for the easy adult text, the Bible. This will be seen to lie close to the data for the Third Reader. Thus the average Third Grader is reading at the level of easy adult text.

The data for children's preferred reading are presented in Tables 6 through 9. Table 6 shows the data from several texts at each of the three reading levels. Figure 3 shows the growth of sequential constraint in the 3 levels of the free-reading choices. It is immediately obvious that Levels 3 and 5 are indistinguishable, and are not different from the two Fifth Readers, all of these lying at the level of average adult text. But Level 3 of the free-reading choices is less redundant than the two readers at this level, and Level 1, though more redundant than Level 3, is still considerably less redundant than either of the first readers.

Children's free-reading choices are, in the early years, less redundant than their readers. It seems probably that, at least at Level 1 and perhaps to some extent at Level 3, these books are read to the child. The point is not whether he can read them, given our current techniques of language teaching, but rather what he enjoys. He appears to prefer language which is less redundant than that presented to him in his readers.

Writers of Readers assume that a very high level of redundancy (as evidenced by a large amount of word, phrase, and sentence repetition) is optimal. The child himself prefers less redundant language.

It was of some interest to investigate the effect of sample size on these measures. One long Level 5 free-choice text (Alice in Wonderland) was used. Random samples of approximately 1,400, 3,000, 6,000, 12,000, and 18,000 words were taken. The results of the computations on these samples are shown in Table 7. All measures appear to be stable at about 6,000 words (approximately 24,000 characters). This we have considered a minimally acceptable sample, but have always used samples in excess of 10,000 words (40,000 characters).

Another question of interest is to what extent style influences redundancy. To answer this, we compared three entire Level 5 free-choice texts and three entire Level 3 free-choice texts. These data are presented in Tables 8 and 9. The first two Level 5 texts are not greatly different in spite of vastly different style and lexicon. Alice in Wonderland is, however, less redundant (cf. Figure 4). This may well reflect a genuine difference in difficulty, comparable to that found by Newman and Waugh (1960) for William James (36%) and the Atlantic Monthly (32%). Mean word length does not appear to vary greatly, but mean sentence length is very much longer in Alice.

Whether mean sentence length or word length is correlated with difficulty is a question which can be answered from our data. If we examine the data for the Level 3 texts, we do see some variation in redundancy, although it is not great. The individual texts are slightly more redundant than the Level 3 sample, composed of parts of the three. But the astonishing thing about these results is the lack of relation between the redundancy of The Emperor's New Clothes and the mean word and sentence length. This text has the longest mean word length and longest mean sentence length we have ever computed. They are longer than those in the more difficult Level 5 text, Alice in Wonderland. The calculated redundancy agrees with the ratings of difficulty in Wilson's Children's Catalogue. It is apparently quite possible to write fairly easy books using long words and long sentences.

The secret, we believe, in writing easy but interesting books is to use a limited lexicon, as in The Emperor's New Clothes, but not to limit it to the few thousand most frequent words in adult language. Rinsland (1945) has shown that, although a single First Grader's vocabulary is limited to 5,000 words (active vocabulary), the total sample of First Graders use all the words the Eighth Graders use. The ones they use depend on their experience, not on the frequency in the adult written language. They can use any word, and they can read any word; they just can't handle too many at one time in either area. A book they like tells them about something interesting and uses the necessary lexicon to do so. Sentence length increases with grade in both readers and free choices. The sentence length in The Emperor's New Clothes is phenomenal. We have not analyzed the relationship between sentence length and grammatical complexity, but it is obvious that there is some relationship. It is equally obvious too that the relationship is not simple. Cases in point are: the tremendous sentence length in the Level 3 text cited above; the decrease in sentence length from Level 5 to adult speech (vide infra); the fact that Strickland (1962) found no regular development of grammatical complexity in Readers; and the large difference in mean sentence length (without other statistical differences) between the two schools in the Fifth Grade and there only.

b. Natural Speech

The analyses of natural speech are presented in Tables 10 through 12. Table 10 shows the relative sequential constraints for both the letter and the phonemic transcriptions. There is very little change in redundancy from First Grade to adult speech in the letter transcription data. For the phonemic data, as Figure 5 shows, the two growth curves are indistinguishable. In terms of sound pattern redundancies, therefore, 6-year old speech is adult; there is no change after age 6. Figure 5 also shows the relative sequential constraints for a First Reader, and for a letter transcription of First Grade speech. Here the difference is sizable, the Reader being the more redundant. Hence, the differences between natural speech and written material may be more important in learning to read than has been previously considered.

In Table 10, H(1) is seen to be characteristic of the language, with the added proviso that the number of characters used is also revelant.[1] Mean word length (letters) increases from 3.6 letters for First Grade speech, to 3.8 letters for Fifth Grade speech. Word length for First Readers is 3.7, rising to 4.1 for Fifth Readers. Word length (letters) for adult speech is not very different, 3.9 (Table 11). Thus is appears that word length is somewhat greater in Readers than in speech. For free-reading choices, there does not appear to be a difference between Level 1 (4.1) and Level 5 (4.0), but both are closer to Fifth than to First Readers. For adult speech, word length (letters) is similar to that of Fifth Reader and all free-reading choices. The shorter mean word length in speech as compared to written texts may be due to the frequent use of 'yes,' 'no,' and personal pronouns, especially in children's speech, and need not give any information about the length of lexical words. This hypothesis can and should be checked.

Phonemic "words" increase proportionately about the same amount with level, adult phonemic "words" being somewhat longer than 6-year olds' "words." It should be remembered that a phonemic word was defined in such a way as to aid in the discovery of the novel features of spoken language. Great caution is necessary in interpretation. A phonemic word, then, is not the same as a lexical word, and is not intentionally related to word classes or syntactical units. It was defined only in terms of prosodical features, specifically a pause in the flow of sound. These units, phonemic "words," are three times as long as lexical words*, and represent a grouping that occurs between pauses. In terms of length, they appear to be more like phrases than words. In any event the pauses do not occur at the same places as the gaps in written language. This discussion raises the important question of the nature of the decoding (auditory) units of language. Insofar as the units of spoken language and written language are different, the learning of written language (reading) will be more difficult.

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[1] Phonemic coding, using a 41-character alphabet, yields more information per letter, than the ordinary English alphabet. Jakobson, Cherry, and Halle (1953) obtained $H(1) = 4.78$ bits for Russian speech, using 42 phonemes.

Turning now to Table 12, we see that mean letter sentence length behaves peculiarly: it is higher in the grades, especially Third Grade, than in adult speech. The letter transcription data for speech can be compared with data from written materials because of the similarity in alphabet and word definition. In making such a comparison, we find that in First and Third Grade speech, the mean sentence lengths (10.0 and 11.5) are similar to those found in free-reading choices (10.1 and 12.2), but higher than in First and Third Readers (6.7 and 10.6). But the mean sentence length of the free-choice material at Level 5 is much higher (16.5) than that for Fifth Grade speech (10.5) and Fifth Reader (12.1). The most difficult individual Level 5 texts had an even higher mean sentence length (18.0). Yet adult speech, on the contrary, shows a drop in mean sentence length (9.7).

There are several possible explanations of this strange state of affairs. In the first place, formal language has a literary norm which places value upon long sentences for avoidance of monotony in both sentence length and grammatical construction. Informal speech, on the other hand, has at least two other tools for use in avoiding monotony--all the several aspects of prosody, and the natural community of interest that sustains the conversation. Speech thus has no need for varied, hence some long sentences. Furthermore, long sentences in formal language virtually demand complex grammatical forms. This can be coped with in writing, because it is possible to start over again when one becomes entangled in the construction. In speech there is no retracing unless one interrupts with "what?" and after a few instances of that, the speaker simplifies his discourse, or the listener walks away.

Secondly, the definition of a phonemic sentence was based, not upon grammatical structure, but upon certain features of the prosody: intonation contour, terminal pause, change of speaker, whereas in written language a sentence is usually a certain type of grammatical unit. Linguists, when pressed, cannot really define a sentence. Indeed, Fries (1952), found different kinds of utterances, some that start a conversation, some that can only be responses, some that produce action responses, and they all have different structures. Many are not in themselves complete grammatical structures of the sort grammarians discuss. Fries' sentence patterns more nearly describe our spoken patterns, because he used a speech corpus, although ours appear to be more fragmentary and less structured than his, even at the adult level. A grammatical analysis has not been attempted with this material yet, so any comments upon this aspect are based upon an impression of the material as a whole. In any event, since our spoken "sentence" was largely determined by a terminal pause, it may be more closely related to vital capacity than to grammatical structure, although one would expect a pause where a natural unit of comprehension occurs. The drop in mean sentence length with adults lends some credence to this supposition. The hypothesis is that the children string together simple syntactic structures with 'and' connectors as long as their breath lasts, in part to avoid interruption. Adults, on the other hand, with more mannerly companions, can afford a syntactic pause. We also find that adults use 'and' much less frequently, using more complicated syntactic structures to convey the more complex relations in their conversations. This hypothesis was checked by a count of the 'ands' at Level 3 and adult. A count was made of those phonemic words involving 'and' (e.g., 'and,' 'an,' 'anun') that occurred three or more times in the Third Grade and Adult corpuses. It was found that the total number of occurrences of such words, after correction for sample size, was approximately twice as great in Third Grade as in Adult speech.

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* A sentence from a Reader is about 40 letters long, whilst a sentence of speech is about 30 phonemes long. However, the 40 arises from $3.8\bar{W} \times 10.5\bar{S}$, but the 30 arises from $10.5\bar{W} \times 2.9\bar{S}$, where $\bar{W}$ is mean word length in symbols, and $\bar{S}$ is mean sentence length in words.

The main point to be made here, however, is that spoken language and written language are again shown to be different, the spoken language tending toward shorter sentences, and presumably, simpler forms. Insofar as they are different, the problem of learning to read is increased.

The relative frequency for each letter for each level of natural speech is shown in Table 13. Again there are no great differences among the spoken samples. Table 14 shows the relative frequency of phonemes for each level of natural speech, where the differences among levels also is small. Reference to Table 15 will show the minor changes. Table 2 shows that the correlations between the letter frequencies used in adult speech and those used at the other three levels are all .99 or better. This is another indication that certain features of speech do not change from six years of age to adulthood. The differences reflected in some aspects of language are more likely to be due to complexity of thought than to genuine language differences.

The stability of phoneme distributions from age 6 to age 20 may be noted in Tables 15A and B which give the rank order of vowel and consonant phonemes by relative frequency of occurrence. Vowels change rank in only five cases (out of eleven) from First Graders to Adults, the percentage changes being +47 (/uw/), -22 (/æ/), -20 (/a/), +8 (/e/), and -7 (/ey/). From an articulatory view the major changes are an increase in the close vowel /uw/ and decreases in the open vowels /æ/ and /a/.

Proportionately fewer consonants change rank (7 out of 25). but only four show large changes (greater than about 15 per cent). From First Graders to Adults the changes in per cent are: +128 (/y/), -45 (/m/), -30 (/g/) and +28 (/l/). These are all voiced consonants, but /l/ and /y/ are both (alveolar) approximants, whereas /g/ is a velar stop, and /m/ is a bilabial, nasal consonant.

We have not considered whether these relatively slight changes reflect physiological and structural changes of the vocal mechanism. An interesting speculation may be based on a statistical study of the larger units of speech that we now have in progress. Preliminary data show that the most frequent phonemic word for First Graders is "um" whereas the two most frequent phonemic words for Adults are "yeah" and "y' know," with "you know" not far behind. This change is consistent with the increase in relative frequencies of /y/, /uw/ (as in boot), and /e/ (as in bet), and with the decrease in /m/. (It is interesting that the most frequent single "lexical" word is "yeah" for adults and "no" for First Graders!).

Tables 16A through 16D give the frequency of occurrence of phonemes in natural speech based on an alphabet of 39 phonemes, omitting word boundary and sentence mark. (see Appendix IV-3). There is a breakdown into the three major categories of vowels, consonants and diphthongs containing proportions about .36, .60, and .04, respectively. These values are in good agreement with relative frequency statistics of English consonants that are presumably based on a speech corpus (Wang and Crawford, 1960; Denes, 1963). To make the tables more useful some further subdivisions were made. Vowels are tabulated in categories front, central and back. Consonants are classified according to three different schemata--state of glottis, manner of articulation, and place of articulation--each with appropriate sub-categories. The three diphthongs are simply listed individually. We shall not discuss these Tables further here. They are presented for the interest of those concerned with developmental phonetics.

Table 17 displays the correlation matrix for 22 consonant phonemes from 15 (actually, it will turn out, 14) sets of data. Data sets 1 to 10 are taken directly from the study by Wang and Crawford (1960). They omitted vowels from their comparisons for the reason that consonants are relatively simple to compare, but vowel systems are difficult because of transcription problems and the relative complexity of dialectical differences.

The nature of the sources and sample sizes of the consonant phonemes used in these computations is listed here inasmuch as some apparent anomalies will be easier to understand if the character of the source material is known. We have consulted all the original sources except for Carroll (1952), but Carroll's original data are given by Hultzén, Allen, and Miron (1964).

1. Trnka (1935), dictionary - 15,459 phonemes - "Nearly all the words used in this work are taken from the Pocket Oxford Dictionary of Current English (London, 1928)." Analysis was restricted to words consisting of one morpheme and containing at most two vocalic phonemes.

2. Fowler (1957), modern prose - 10,194 phonemes - (5000 phonemes each from a narrative an an essay by Graham Greene, Concepts of the Calculus by Boyer, and the entire 501 phonemes from The Story of a Fierce Bad Rabbit by Beatrix Potter. Apparently the data from Boyer and the 501 phonemes from Potter were not used by Wang and Crawford).

3. Carroll (1952), juvenile plays - 10,784 phonemes (taken from Wang and Crawford).

4. Hayden (1950), lectures - 41,412 phonemes.

5. Whitney (1874), "modern prose" - 6,371 phonemes: from 5 poems (Shakespeare, Milton, Gray, Bryant, Tennyson) and 5 prose passages (Bible, Dr. Johnson, Goldsmith, Carlyle, and Macauley).

6. Dewey (1923), newspapers - 235,025 phonemes.

7. Voelker (1937), radio announcements - different announcers, 409,506 phonemes.

8. French, Carter, and Koenig (1930), long-distance telephone business conversations, a different part of speech sampled on successive days - 135,548 phonemes.

9. Fry (1947), phonetic readers, short simple anecdotes for foreigners learning English - 10,305 phonemes.

10. Tobias (1947), telephone conversations; a different phonemic coding of material from Study 8 - 133,460 phonemes.

11-14. Carterette and Jones (1965), phonemic transcriptions of natural speech from the present study, number of phonemes: First Graders, 35,153; Third Graders, 37,855; Fifth Graders, 48,579; Adults, 28,988.

15. Hultzén, Allen, and Miron (1964), same data as Carroll (Study 3) - 10,657 phonemes.

The correlations among items 1-10 were recomputed using the distributions of Wang and Crawford (1960) and the values of *r* obtained are identical with those calculated by them.

The most salient and important features of this table are: (1) the very high correlations (.88 and greater) among our data (First, Third, Fifth, and Adult speech), HAY, WHI, DEW, VOE, FRE, and FRY; (2) the relatively low intercorrelations between these sets of data and TRN, FOW, CAR, and HULTZÉN. The correlation of 1.0 between the Carroll and Hultzén data comes about because Hultzén, Allen, and Miron (1964) used Carroll's data as the basis for their study of transitional frequencies of English phonemes. It appears that the highest correlations occur between phonemic systems derived from material closest to natural speech, whereas the lowest correlations occur with phonemic systems based on material furthest from natural speech. To illustrate, Third Grade speech has the highest correlations (.90 or higher, accounting for 81 to 85 per cent of the variance) in decreasing order, with VOE (radio announcements), FRY (phonetic reader), HAY (lectures), WHI ("modern prose"), DEW (newspapers), and FRE (telephone conversations), but the lowest correlations (.80 to .62, accounting for 64 to 39 per cent of the variance) with FOW (modern prose), TRN (dictionary) and CAR (modern plays), *r* being least for the last. The Hayden corpus is more nearly like speech than any of the others. Since her system of transcription was virtually identical with ours, we were able to correlate the proportions of phonemes for her data with our adult data for 38 phonemes, consonant and vowel. In spite of the transcription difficulties and dialect differences for vowels, the correlation is relatively high: .88.

Hultzén, Allen, and Miron (1964) claim that the low correlations obtained between the Carroll data and all but two sets of data in the Wang and Crawford analysis were due to use of a different system of phonemic analysis for the Carroll data. By subtracting certain complex syllablic nuclei from the totals for /w/, /y/, and /h/, they obtain much higher correlations than those given by Wang and Crawford. For example, Wang and Crawford's correlation of .63 between Carroll and Hayden becomes .98 as calculated by Hultzén, Allen, and Miron. However, it should be noted that Hultzén, et al.'s Table 2 (page 14), showing the distribution of phoneme frequencies, appears to contain the original Carroll data, since its correlation with the latter is .999 as calculated by us in our Table 17. In any case, Hultzén, Allen, and Miron use the original Carroll data to obtain the transition-numbers of 20,032 phonemes from which they compute the relative sequential constraint for diphones (C_2), triphones (C_3), and tetraphones (C_4). We note that these are exact values which take account of all constraints, and are presented in the table below, right-hand column. They compute C_k from $H_{max}(1) = \log_2 43 = 5.43$, assuming equiprobable occurrence of any phoneme.

	Phoneme Pairs	*k* - Phones		
C_k	$H_{max}(1) = 4.84^a$	$H_{max}(1) = 4.84^a$	$H_{max}(1) = 5.36^a$	$H_{max}(1) = 5.43^b$
C_1	.00	.00	.10	.15
C_2	.19	.19	.19	.36
C_3	.26	.36	.43	.55
C_4	.28	.42	.53	.70
C_5				.88
C_6				.92

a. this study
b. Hultzén, Allen, and Miron

For comparison we give values of C_k computed by us from sample of 66,253 phonemes transcribed from the speech of First Graders. Values in the first column were computed on phoneme pairs as described in

Section 4A-3. The values in columns two and three are exact values, the first computed for the base $H_{max}(1) = 4.84$ (each phoneme weighted according to its estimated probability of occurrence in the entire sample), the second computed for the base $H_{max}(1) = 5.36 = \log_2 41$ (the assumption of equiprobability). Thus, columns three and four may be compared because the computations were made relative to the same base. The relative sequential constraint* of modern plays averages 15 per cent more than that of the free speech of First Graders. Since we found First, Third, Fifth Graders and adults to have indistinguishable relative sequential constraint, we conclude that the text used by Hultzén, Allen, and Miron is highly redundant if it is assumed that their sample is sufficiently large. Contemporary dramatic speech for a juvenile audience is apparently very different from contemporary natural speech. Wang (1965) claimed, on the basis of peculiarities of diphone frequencies, that the Hultzén et al. data are not representative. Had Hultzén et al., used a larger sample, it is likely that the measured redundancy would have been ever greater. This follows from Miller and Madow's (1954) proof that H(1) underestimates the true value of H(1), and is consistent with our sampling experiments (Jones and Carterette, 1963, Table 3, page 492). Furthermore, we computed the values for C_5 and C_6 from the equation given by Hultzén et al., which they proposed as an adequate fit for C_1, C_2, C_3, and C_4. Even their value of C_4 far exceeds any published estimate of letter redundancy that we have seen.

C. Main Experiment

The results of the analyses of variance are presented in Tables 29 through 34. One set of analyses (Tables 29 and 30) was done using all the subjects, another separating children and adults, because of the peculiarity of the "school" variable for adults.[1] In each case, it was necessary to analyze separately for the two types of errors, "new" errors made by calling an old stimulus new, and false alarms made by calling a new stimulus old, as in the pilot study. A comparison of these two kinds of errors can be obtained from Table 35 A and B, which show the different way in which to two kinds of errors operate. For "new" errors, auditory presentation produces fewer errors in every case, but for false alarms it is visual presentation which occasions fewer errors. Reference to the analyses of variance for the total group (Tables 29 and 30) shows that modality is significant in both cases, though in opposite directions. What this apparently means is that auditorially presented material is processed more easily than that presented visually. Words are more often recognized auditorially - and also more often falsely recognized. It should also be noted that low frequency words--but still words--are more often falsely recognized than either very familiar ones or words that have clearly never been encountered, both of which can be easily coded, and therefore more easily recognized. This is not true for "new" errors, where non-words seem new even after having been presented once before in the experiment. In Table 36 A and B, Frequency by Reading Level errors are shown. Low frequency words cause fewer "new" errors than non-words, but more false alarm errors. The differences between low-frequency words and non-words are larger for adults for both "new" errors and false alarms (plus for false alarms and minus for "new" errors) than for First Graders. The Third and Fifth Graders behave like adults in false alarms, and like First Graders in "new" errors. This is borne out by the significant interaction of Reading Level by Frequency (Table 29 for "new" errors, and Table 30 for false alarms). First Graders have a high false alarm rate, i.e., a bias in favor of errors of commission (cf. ROC curves below). The other three groups do not make nearly as many false recognitions for high frequency words as they do for low-frequency words. For all groups the differences between the number of false alarms produced by high-frequency words and by non-words are not large. These are clearly fish or fowl; it is the low-frequency words that are hard to classify. Since this difference between First Graders and the others shows up in false recognitions alone, it may be that it is a more sensitive measure of difficulty in accurate processing of language than failure to recognize; at least it is a different function, which might be useful in assessing recognition vocabulary for reading.

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* Note that C_1 is identical with H(1) and does not measure sequential constraint but only redundancy relative to optimal encoding.

[1] In order to have equal cells, the adult group was randomly dispersed among two "schools," as pointed out earlier.

The analysis of variance for all subjects for "new" errors is shown in Table 29. Four main effects are very significant: modality, school, reading level, and frequency. Since, in this analysis, school is highly correlated with reading level (schools 3 and 4 were a Junior College), it should be ignored in this context. Frequency of occurrence is obviously of tremendous importance in processing language, and so is reading level.[1] There are also interactions of modality and of reading level with frequency which are moderately significant. In the analysis of false alarms for the total group (Table 30), modality, reading level, and frequency are again significant, and so are the modality by frequency and reading level by frequency interactions, but list also becomes a significant effect, as do two interactions with it (list by frequency, modality by list by frequency). As we noted in connection with the pilot recognition experiment, the lists are extremely difficult to randomize because there exists only a small pool of items of very high frequency of occurrence in the language, and from this auditory honomyms and confusable phonemes must be eliminated. The modality by list by frequency interaction tells us that the lists are not the same when visually presented as they are when presented auditorially. This should be obvious, but is not usually mentioned in studies of auditory verbal learning. The list frequency by interaction tells us that the lists do not contain the same frequency relationships.

When we analyze the "new" error data separately for children, we find modality, reading level and frequency again significant (Table 31). Modality by frequency is significant, and so is school. The comparable adult data are shown in Table 33, where the only main effect which reaches significance is frequency, and that very significantly.

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[1] Here also confounded with mental age.

The false alarm analyses are shown in Tables 32 and 34. Here modality is significant for the adults ($p < .01$) but reaches only the .10 level for children. There are, of course, no reading-level measures for "adult-only" data, but reading level is significant for children. Frequency is still extremely significant for both groups. Again we get a number of interactions, many of which involve list, and list itself is significant. This agrees with the results of the overall analysis. There appear to be more significant interactions for children than for adults, but this is partly due to the fact that there are more real variables: school and reading level. The modality effect finds expression in interactions rather than primarily as a main effect.

Comparison of the total errors made by adults and by children is of interest. These data are shown in Table 37 A and B for audition and vision separately and for the totals. Differences between auditory and visual errors are also shown for each reading level. Children make more errors of both kinds than adults in both vision and audition, and the younger the child the more errors he makes. Audition is easier than vision for First Graders, not only in "new" errors, but also in false alarms, reflecting his greater familiarity with auditory language. Table 37 seems to show that auditory presentation has progressively less advantage for new errors as age increases although it does not quite reach statistical significance, due probably to the sizable variability of scores, especially at the lower ages. For false alarms, the same table shows a less regular advantage for vision; in fact First Graders make more visual than auditory errors, whereas the others all make fewer false alarm errors in vision. The trends appear interesting enough to warrant further investigation, comparing auditory and visual processing in the same individual. It is important to know whether vision and audition operate equally efficiently in the same individual. It would also be profitable to explore more thoroughly the differential between visual and auditory recognition as a function of age in order to ascertain which method of presenting information is more accurate at each major instructional level. It may be foolish, for example, to continue to lecture to college students if their overall processing of auditorially presented information is inferior.

Tables 38 A and B and 39 A and B present the errors for frequency by reading level for audition (Table 38) and for vision (Table 39) separately. For auditory presentation the largest number of "new" errors occurs in non-words for all ages, whereas the largest number of false alarms occurs for low-frequency words. This is true even for adults. A non-word may be novel enough to be categorized easily; a low-frequency word is not as easily categorized because it has some elements of familiarity; a high-frequency word is again easily categorized. The visual data show similar trends at the three highest levels, but First Graders are quite different, as one might expect. For "new" errors, First Graders have as much trouble with low-frequency words as with non-words, since for them they are not different, but high frequency words are easier than the other two categories. On the other hand, the false-alarm rate shows little frequency effect with First Graders, whereas the other three levels make many fewer false alarms for high-frequency and non-words, but tend to wrongly recognize low-frequency words, just as they did with auditory presentation.

This analysis shows the First Graders to be different from all other groups in visual but not in auditory language processing, which would be predicted if the measure is sensitive. Since the analysis of the false alarm data shows that they contribute to the way in which language is processed differently by the various age groups, a more precise way of using the combination of new errors and false alarms is to be found in the ROC curves.

A useful way of combining the individual data is the so-called Receiver Operating Characteristic, usually shortened to ROC curve. While many of the uses and interpretations of ROC curves depend on various theoretical models (see, e.g., Swets, 1964), it is nonetheless true that much descriptive power arises from geometrical considerations of ROC plots which are based on only a few quite reasonable assumptions (Norman, 1964). After describing how to make ROC curves, we shall use Norman's method to make comparisons of performance levels.

The probabilities which are necessary to construct an ROC curve may be estimated by using the data of N trials from the recognition experiments. In order to make our analysis consistent with signal detectability theory we shall plot on one axis the proportion of correct recognitions of new words, p("new"/new), that is just one minus the proportion of false alarms; and on the other axis the proportion of new errors, p("new"/old). Two numbers are required: the conditional probability that the child says "new" when a new pattern is presented, p("new"/new), and the conditional probability that he says "new" when an old pattern is presented, p("new"/old) (see Figure 6). The first is given by

$$P(\text{"new"}/\text{new}) = \frac{N_{nn}}{N_{nn} + N_{no}}.$$

and the second by

$$P(\text{"new"}/\text{old}) = \frac{N_{on}}{N_{nn} + N_{on}}.$$

The subscripts "o" and "n" refer to old and new, the first giving the presented pattern, the second giving the response.

The relationship between correct detections (equal to one minus the number of false alarm errors) and "new" errors shown in Tables 40 and 41, is as follows. The conditional probability that a subject responds with "new" when a new item is presented, p("new"/new), is given together with the corresponding conditional probability that he responds "new" when an old item is presented, p("new"/old). These pairs of values are shown for each of the 32 subjects in the auditory recognition task for the First, Third, and Fifth Graders and Adults, respectively (Table 40). Table 41 gives the corresponding values for the 32 subjects in each of the four visual recognition task groups.

Since p("new"/new) + p("old"/new) = 1.0, p("old"/old) + p("new"/old) = 1.0, and of the 180 words presented to a subject, p(new) = p(old) = 1/2, the raw mean scores for any subject can be recovered by a simple multiplication rule. For example, the total number correct, N(c), is given by

$$
\begin{aligned}
N(c) &= 90\left[p(\text{"new"}/\text{new})\; p(\text{new}) + p(\text{"old"}/\text{old})\; p(\text{old})\right] \\
&= 90\left\{1/2\; p(\text{"new"}/\text{new}) + 1/2\left[1-p(\text{"new"}/\text{old})\right]\right\} \\
&= 45\left\{1-\left[p(\text{"new"}/\text{old}) - p(\text{"new"}/\text{new})\right]\right\}
\end{aligned}
$$

The reasons for wishing to plot the data in this way are many, and details are to be found in *Signal Detection and Recognition by Humans* (Swets, 1964). We can summarize the reasons as follows: A simple score such as number of "yesses" to a new pattern can be misleading because two different subjects may have equal scores, but one may make very few false-alarm reports (that is, call *old* patterns "*new*") and the other may have a high proportion of false alarms. Hence a truer picture of the subject's performance is given by a detectability index, d', which incorporates both the detection rate, p("new"/new) *and* the "new" error rate, p("new"/old). There are two very important properties of this index. One is that if the difficulty of a task is fixed during a series of trials, it is not possible for a subject to increase his "hit rate" without also making more errors. The other is that the detectability index has been shown to be relatively independent of the subject's motivation, the costs of errors, the reward for hits, the experimental conditions, instructions, and the like.

An example will be helpful. In the graph of Figure 7 (Grade 3, Audition) the child represented by the point lying furthest to the right has a detection rate of .78 and an error rate of .55. There are, however, nine other children represented by points to his left (lower error rates) and lying on or above the horizontal line, p("new"/new) = .78(i.e., having an equal or better hit rate). There is a similar (and larger) rectangle lying below and to the right of this point which defines an inferior performance. Norman (1964) has derived a simple graphical procedure that allows comparison to be made among experimental conditions, with very limited assumptions about the underlying processes. He shows that the unit square (the ROC domain) may be partitioned into four regions in such a way that any arbitrary performance level represented by a single point may be related to that of any other point in the region. Thus in Figure 6, (Grade 1, Auditory), let us take that point given by the mean value of p("new"/new) and p("new"/old) (solid circle) to represent the mean performance level. The pair of straight lines drawn through the point from the two corner points (0, 0) and (1, 1) define four regions. The performance levels of subjects whose points lie in the regions S are *superior*; in the region I, *inferior*; and in the regions A, *ambiguous* with respect to the mean performance level.

These regions have been indicated on all 8 graphs of Figures 6 through 13. In addition, the regions for Grade 1, auditory are shown as dashed lines on the graphs of auditory results for Grade 3, Grade 5, and Adults. Likewise, the Grade 1, visual results are also shown as dashed lines on the graphs of Grade 3, Grade 5, and Adult visual results. This makes it possible to compare the points on a graph with the mean performance level of that group or with the mean performance level of the First Graders. For convenience Table 42 shows the proportions of the 32 individuals in each group having a performance level superior to the mean performance level of First Graders or of the parent group. The main result of this analysis is apparent in the first two lines. The proportion of individuals whose performance on the auditory task is superior to First Graders increases approximately linearly from First Graders to adults whereas the increase for vision is rapid and non-linear. By Grade 5 only one child has not exceeded the performance of First Graders on the visual task. But in the auditory task 6 of the 32 Fifth Graders have failed to exceed the mean performance level of First Graders. However, no adult in either task fails to exceed the First Grade performance level.

The two lines showing the proportion of the 32 individuals in each group who clearly exceeded the mean performance (fell in region S) within his own group, reveal nothing more than the fact that about one-third have performance levels exceeding the mean performance level.

More complex comparisons among pairs of points may be made by Norman's method. Pollack and Norman (1964) (see also Pollack, Norman, and Galanter, 1964) have extended this method by showing how to transform the data of recognition experiments into an equivalent two-alternative forced-choice score, the probability of a correct choice P(c). The important advantage of this transform is that P(c) is relatively free of perturbations due to bias, whereas recognition scores are not. Also Green (1964) has derived a general prediction relating yes-no and forced-choice results.

What interpretation can be made of the above dryly stated facts, by extension from the recognition experiments to the larger world of the developing child? One is that when he begins schools his auditory perceptual skills are probably superior to his visual perceptual skills. But once concentrated tuition begins, heavy demands are made on the intake of information by eye in reading, and in negotiating a complex world that is like a dense forest with a discriminative stimulus for every tree. That the visual performance of a Fifth Grader is essentially as good as that of an adult is quite consistent with our finding that a Fifth Reader and average adult texts have approximately equal redundancy. The better beginning and slower growth of auditory skill in the recognition task is consistent with our finding that simple sequential constraints of phonemes are essentially equal for First, Third, or Fifth Graders, and Adult. There is, of course some further differentiation from First Graders to Adults when the distribution of phonemic words is considered.

We suggest that a useful fruit for the educator might come from an exploration of a given child's performance index for visual and auditory material. Not only could his auditory and visual performance be related to each other. They could be related to group norms obtained in a standardized recognition memory experiment, and to other independent indices of ability such as Wechsler-Bellvue sub-test scores, grades, or even actual reading performance. The advantage of the recognition task is its minimal demands on auditory or visual perception, making it useful over a wide range of ages. The advantage of the ROC plot lies in the freedom of the detectability index from perturbation by criterion, motivation, implicit (but unspecified) reward and cost schemes, and other variables extraneous to the test situation but, alas, ubiquitous.

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9.

Conclusions and Implications: Statistical Studies

1. Written Material

The amount of selective information in single letters (Shannon's (H (1)) is about the same for all texts ranging from the simplest children's Reader to very difficult adult text. In fact it is very close to 4.1 for all sources examined by us, independent of the particular sample. It appears to be a characteristic of English text.

It is possible to quantify written texts in terms of letter redundancy and this measure of redundancy was found to relate to the difficulty of the material as judged by other standards. The measure of relative sequential constraint, C_n, ordered two series of Readers in regularly decreasing constraint, and also showed the two series to be very similar at each level examined, First, Third and Fifth. Mean word-length increases slowly but similarly with increasing level in the two graded series, whereas it apparently varies slightly but randomly in free-reading choices. Mean sentence-length is similar in the two series and grows regularly, but is very much greater in the free-reading choices at all levels. This restriction in sentence length in Readers implies a restriction of grammatical form. It is apparently possible to control the difficulty of textual material by the usual method: restriction of vocabulary and sentence length.

Third Readers are about as redundant as simple adult text; Fifth Readers are like average adult text. Similar computations for three levels of children's preferred 'free-choice' reading proved them to be less redundant, at the earlier levels, than Readers: Levels 3 and 5 are comparable to average adult text; but Level 1 is considerably less redundant than the First Readers. Children apparently prefer less redundancy than occurs in their Readers. This finding implies that the practice of reading to children while they are in the early stages of learning to read is probably a good one.

It is probably not possible to write Primers at the preferred level of redundancy. However, an interesting way of attempting to do so suggests itself. Careful editing and reduction of a text less redundant but more interesting than a Primer might result in a new vocabulary restricted enough to be more redundant, yet still capable of being used to write an interesting story.

This measure of redundancy proved to be stable when the sample size reached 6000 words. Neither was it greatly affected by style. Redundancy was shown to be uncorrelated with word length or sentence length. It was concluded that, although . limited lexicon is necessary for texts intended to be redundant, and easy to read, it is not necessary to limit the lexicon to the most frequently occurring words in the language. It is the latter procedure which makes for dull books.

Readers should be written, then, with a limited lexicon, but one which is selected because it can be used to tell an interesting story. Since the reinforcement which helps to build reading skills arises largely from the process of reading itself, it is of utmost importance to utilize interest in the learning process.

2. Natural Speech

The proportional frequencies with which the several letters are used is is very similar among child and adult written texts, and among child and adult spoken language. Prediction of the proportional frequencies of the 26 letters in adult text from the proportional frequencies in a First Reader is virtually perfect--97 per cent of the variance is accounted for. But prediction of the proportional frequencies in First Grade speech from a First Reader is just as good. Proportional frequency is not, however, a very sensitive index of differences in language. For example, the proportional letter frequencies of First and Fifth Readers are almost perfectly correlated but their redundancies, as measured by sequential constraint, are very different. Similarly, proportional frequencies of consonant phonemes correlate highly among samples of speech but proportional phoneme frequencies from speech samples do not correlate highly with those from written samples, *even though the written material is intended to be spoken*, as in plays. There is very little change in the rank order distribution of phonemes from 6-year olds to adults. Thus even in a crude measure, speech is demonstrably different from written material.

There is very little change in redundancy from the speech of 6 year-olds to that of adults, in the letter transcriptions. For the phonemic data, the curves of growth of sequential constraint for 6 year-old and adult speech are indistinguishable. On the other hand there is a sizable difference between the letter redundancy of the speech of 6 year-olds and that of the First Reader, the latter being much more redundant.

Mean word length in terms of letters (ordinary lexical words) grows slightly from First Grade to adult speech, and is not very different from the word lengths in the comparable Readers or in easy adult written text. Phonemic words, on the other hand, are much longer than lexical words because they were defined by pauses. These phrase-like units also grow slightly in length with age. Insofar as these phonemic words can be considered to indicate natural units of language, they provide added information about the differences between spoken and written language. Phonemic words are much longer than lexical words, and the word breaks do not necessarily occur at the same places that breaks between groups of lexical words occur.

Mean sentence length was found to be less in adult speech than in child speech, which was attributed to the child's tendency to string utterances together with one of the coordinating conjunctions, 'and.' But mean sentence length in children's speech is greater than that found in their Readers at the earlier stages.

There are two important implications to be derived from these data.

The first of these is that six-year old speech is very close to mature speech, a finding in agreement with the overwhelming majority of studies of many aspects of child language. These data add significantly to this body of evidence in that different kinds of language samples at a wide range of ages, as well as larger samples were employed, and sequential constraints were investigated to yield a quantitative measure of differences among language samples. The conclusion that six-year old speech is virtually mature in many aspects should be taken seriously be educators, for it implies that much of the basic language learning is complete before a child starts school, and it is not likely to be as readily modifiable as would be the case if the child were just learning his native tongue.

The second important implication is that there are large and significant differences between spoken and written language, differences more profound that has been evident heretofore. These differences should be explored in further detail. Until the characteristics of spoken language are fully described and compared to those of formal written language it will not be possible to appreciate the specific difficulties involved in learning to read. Once these differences have been elucidated, it will be possible to approach the problem analytically. It should be possible then to devise specific procedures for each kind of difficulty which may arise from the many areas of lack of congruence between spoken and written language. Improvement of reading instruction can be expected only when the complex problem is analyzed into its component parts. This research points to the necessity for such an analysis and indicates certain ways in which the two languages differ. Further research should be directed toward elucidating these differences. This method of quantifying language could be used in comparing various sorts of language samples. We have provided a normative sample of natural speech at First, Third, and Fifth Grade levels and an adult sample. This norm is very close to standard American English, with the added modification that it was derived from individuals of middle socioeconomic level who lived in Southern California. Since we have provided a quantitatively described norm, other samples of speech can be compared to it. Some of the problems which are of interest are a comparison of children's dialects from several parts of the country, a comparison of the speech of children from deprived and superior linguistic environments, and a comparison of the speech of children from culturally deprived areas with the norm.

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Conclusions and Implications: Experimental Studies

Pilot studies on the effect of the frequency of language occurrence of words upon memory revealed that the usual methods of measuring verbal learning were not sensitive to differences in frequency. Neither was short-term memory sensitive to frequency effects. However, a new task, requiring continuous processing of information for recognition after some unknown interval, showed considerable sensitivity to language frequency. This is to be expected, since there is some evidence that recognition tasks reveal the frequency effect more strongly than recall tasks. Furthermore, the new task resembles more closely the reading process in that it requires that verbal material be sequentially processed and that words be recognized as related to some other that occurred previously. Two tasks were shown to be excellent ways of studying verbal learning in children: (1) Peterson's short-term memory technique is very effective with children. It is easy for them; they do not dislike it; it is possible to use a larger number of items than in paired associates or serial lists, a point of no small importance, considering the problems of list idiosyncracies discussed previously. (2) The continuous processing for recognition of a long list is likewise very effective with children. They like it and are good enough at it so that the identical lists can be used with adults and six-year olds with good sensitivity at both extremes. The added advantage is that a very large number of items (at least 90) can be used in a single list, so reducing errors of measurement. Thus one of the four major implications of this project is considered to be the demonstration of the usefulness of two new methods of studying verbal learning in children which are vastly superior to the traditional paired associates and serial lists.

The main experimental findings are based upon the sequential processing task. Since it requires of the subject a kind of information processing which is more like the process of getting information from the printed page, it is considered that the results are more pertinent to learning to read than are the sorts of verbal learning tasks reported in the literature. There are four major findings: (1) There is a strong frequency effect at all levels. (2) Modality is a significant variable in language processing. (3) False recognitions are as important as part of language processing as are failures to recognize. (4) Children make more errors than adults both in failure to recognize and in falsely recognizing, even on words of extremely high language frequency.

1. The discovery of a very significant frequency effect at all levels of language maturity implies that the greater the experience with language the better the recognition of recently experienced items will be. The fact that adults make fewer errors of both kinds than children does imply the same thing. For First Graders there is little difference between low-frequency and zero-frequency items visually presented because there is no difference in the frequency with which they have been experienced visually; there is a difference between these two categories when presented auditorially because there is a difference in the frequency with which they have been experienced auditorially. This finding supports our general contention that there is a difference between aural and written language, in

this case specifically that transfer of the frequency effect from aural to written language is not perfect, even if strong. This implication for training in reading is that there should be a tremendous amount of practice in recognizing words. The implication for training in language skills in general is that the more experience a person has with language, the better. That even a low frequency of experience with a verbal item has a significant effect on recognition is evident in behavior toward low frequency items. Items of low experiential frequency can be expected to give more trouble in reading than either high frequency or zero frequency items, both of which are distinctive. The low frequency items are better recognized than those of zero frequency, but also tend to evoke more false recognitions. They will therefore cause confusion until they are sufficienty well practiced to move into the readily coded group of items. The implication is that introduction of new vocabulary should be accompanied by sufficient practice to bring the item into the easily coded group. The amount of practice necessary to shift a word from low frequency to high at any desired ages could easily be determined experimentally. This should be done because of the immediate applicability to teaching.

2. Auditory and visual processing of language are different. Words of all frequencies are easier to recognize auditorially at all ages, in agreement with the findings of other experimental studies, but they are also more often erroneously recognized auditorially by all except First Graders. The greatest number of errors for every age occurs for false recognition of low frequency words auditorially presented. There is the clear implication here that the cues involved in visual and auditory recognition are different, even though considerable recoding between the two modalities may take place in short-term or long-term memory. The previous recommendation that new vocabulary words should be sufficiently practiced to bring them into the high frequency category should be extended to include both visual and auditory practice. Certainly for young children, auditory practice will result in greater success, but since the transfer is not perfect, it will also be necessary to bring visual recognition up to the level at which a word moves into the high frequency range. It should be possible to specify the amount of training necessary in both vision and audition to bring about this effect at any level of mental age.

3. The importance of the role of false recognitions can hardly be overestimated. Subjects at all reading levels make more false recognition errors than errors of failure to recognize, that is to say, erroneous recognition is an important aspect of processing verbal materials. One can expect that in reading, false recognitions may account for a larger proportion of difficulties of comprehension than does sheer ignorance of lexical items, and since this aspect of language processing is not normally assessed, a large source of variance in the differences between readers is being overlooked. It is in false recognitions that the low frequency words show themselves to be special trouble spots. In errors involving failure to recognize, low frequency words appear to be intermediate between those of high and those of zero frequency, but they occasion far more false recognitions than either of the others. This implies that in reading, low frequency words will cause the greatest amount of trouble in reading comprehension. In our statistical analysis of redundancy, we found that a particular Level 3 free-choice text was considered easy and proved to be

redundant, in spite of having extremely long words--and words of low frequency of occurrence in the natural language. However, these low frequency words, once introduced, were used over and over, so became, in effect, high frequency words and therefore easily processed. The implication from our experimental data is that this is just the procedure which should be followed in introducing new words.

The use of ROC curves to assess the precision of word recognition is an important contribution. These curves take account of both failures to recognize and false recognitions and so are more precise in their evaluation of an individual's total performance. They are also relatively independent of motivation, experimental conditions and the like, hence are more likely to give a reliable estimate of performance. Since a child's reading comprehension is dependent upon both his failure to recognize words and his false recognition of others, this measure, which combines the two, should be superior to measures of either alone in prediction of performance. It would be easy to devise tests of this sort for specific materials and to establish norms based upon the performance of excellent readers. It would also be possible to compare auditory and visual performance to investigate experimentally the possibility that they relate differently to reading performance. It is suggested that such measures be applied to an analysis of reading at all levels and that the effect of practice be followed at various intervals of time.

It is apparent from the ROC curves that First Graders have a bias in favor of errors of commission, i.e., a high false alarm rate. One would predict that their reading progress would be slower because of it. An experiment should be performed to investigate the effect of this bias upon the ROC curves. Establishment of a bias toward omission (failure to recognize) might be expected to sharpen the precision of word recognition and could lead to more rapid progress in reading, providing the situation be manipulated so that it did not become discouraging. On the other hand, it is quite possible that errors of commission do lead to more rapid learning. It would be well to know the answer. It is likely that these sets are influenced by teacher attitudes in any event, and they should know what they wreak. It would also be useful to know whether they can be readily changed, and also whether they are related to Kagan's (1965) "response styles" and thus to a relatively profound temperamental trait which is difficult to modify (cf. also Kagan, Moss, and Sigel, 1962).

4. The fourth major point is that children, even children who read well, make many more recognition errors than adults even on words which are of extremely high frequency of occurrence. This is true both of false recognitions and of failure to recognize and in auditory as well as visual perception. This basic difference between Fifth Graders and adults is probably due to factors related to mental age, though this hypothesis could be checked, and probably sets a limit on the length of linguistic sequence that can be accurately processed. It would be profitable to attempt to relate mental age, errors in recognition over longer delay intervals and ability to comprehend sentences of various lengths and depths (Yngve, 1962).

In conclusion, we find that this project has been highly successful in the following four ways.

1. Samples of language, both written and spoken, were successfully quantified in a way which is meaningful in other contexts and can be used to quantify the difficulty of a text or the differences between spoken language of various culture groups, e.g., six-year olds from deprived environments with six-year olds from enriched environments, or the similarity of speech and reading material.

2. Great differences have been shown to exist between spoken and written language, differences so great as to force a change of opinion about the nature of written language and the cognitive processes involved in the task of learning to read. It is no longer possible to entertain the theory that written language is merely a translation of natural spoken language into visual symbols. Written language is a different language, and the techniques necessary to teach it effectively must be different. Insofar as aural language is to be used as a guide, the nature of the spoken language should be analyzed and bridges built from it to the written language to show relationships, where they exist.

3. Two very useful tasks for studying verbal learning in children were uncovered. These can be used in many other situations where less appropriate tasks are now used, and more detailed information about verbal processes in children should result.

4. A number of specific and testable hypotheses regarding methods of teaching reading and other language skills have been proposed as a result of both the statistical and the experimental work. These hypotheses are both more basic and more precise in their statement of the ways in which children process language than has been possible heretofore.

The following procedures were suggested:

1. Application of ROC techniques to data from recognition tasks as a means of assessing useful reading vocabulary, since false recognitions are hypothesized to cause more trouble than failures to recognize.

2. Comparison of ability to process visually and auditorially presented language in the same individual and their relationship to reading prowess.

3. Investigation of the relationship between the efficiency of processing visual and auditory language as a function of age.

4. Determination of the amount of practice required to make new words a useful part of the reading or listening vocabulary at each level.

5. Measurement of the amount of transfer between practice in auditory language and performance in written language.

6. Exploration of bias toward errors of omission or commission as an important factor in early reading progress.

7. Analysis of the relationship of mental age and level of linguistic ability to length of delay interval for recognition of linguistic materials.

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Appendix I: ACKNOWLEDGMENTS

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Appendix II: TABLES

TABLE 1

Proportions of Each Letter in Adult and Child Reading Material and Adult and Child Speech.

	First Grade Speech[1]	Third Grade Speech[1]	Fifth Grade Speech[1]	Adult Speech[1]	Adult Text[2]	First Reader[3]	Third Reader[3]	Fifth Reader[3]
A	.0823	.0617	.0808	.0759	.0788	.0811	.0800	.0804
B	.0167	.0158	.0151	.0149	.0156	.0270	.0216	.0156
C	.0180	.0180	.0184	.0193	.0268	.0241	.0214	.0210
D	.0452	.0463	.0430	.0468	.0389	.0412	.0485	.0513
E	.1194	.1176	.1208	.1160	.1266	.1204	.1225	.1310
F	.0131	.0129	.0138	.0144	.0255	.0132	.0195	.0213
G	.0237	.0223	.0234	.0242	.0187	.0186	.0241	.0224
H	.0700	.0711	.0702	.0663	.0574	.0602	.0739	.0745
I	.0647	.0641	.0627	.0697	.0706	.0622	.0590	.0577
J	.0019	.0020	.0023	.0034	.0010	.0025	.0026	.0012
K	.0123	.0153	.0155	.0140	.0060	.0183	.0127	.0110
L	.0334	.0346	.0355	.0411	.0394	.0478	.0431	.0428
M	.0361	.0303	.0258	.0195	.0243	.0250	.0195	.0217
N	.0717	.0709	.0668	.0645	.0705	.0642	.0613	.0648
O	.0809	.0815	.0820	.0880	.0776	.0827	.0802	.0771
P	.0111	.0124	.0127	.0131	.0187	.0149	.0152	.0156
Q	.0003	.0002	.0003	.0004	.0010	.0007	.0008	.0005
R	.0418	.0436	.0444	.0468	.0594	.0462	.0557	.0549
S	.0576	.0597	.0619	.0554	.0631	.0561	.0534	.0583
T	.0967	.0943	.0954	.1004	.0978	.1056	.0947	.0919
U	.0337	.0364	.0362	.0395	.0280	.0270	.0281	.0264
V	.0073	.0068	.0091	.0102	.0102	.0023	.0070	.0070
W	.0316	.0322	.0306	.0290	.0215	.0318	.0306	.0286
X	.0012	.0007	.0010	.0012	.0016	.0011	.0009	.0015
Y	.0291	.0289	.0315	.0361	.0201	.0446	.0228	.0202
Z	.0003	.0003	.0006	.0005	.0006	.0010	.0008	.0009
Total Number of Letters in Sample	72,742	78,065	101,618	61,269	372,729	37,728	43,201	51,005

1 Our own tape recordings, letter transcription
2 Dewey (1923)
3 Ginn Basic Reader

TABLE 2

Product-moment Correlation Matrix for Relative Frequencies of 26 Letters from Ginn Readers, General Adult Printed Language, and 1st, 3rd, 5th, and Adult Speech.

		2	3	4	5	6	7	8
1	First Grade Speech[1]	.998	.996	.997	.97	.98	.98	.98
2	Third Grade Speech[1]		.998	.99	.98	.98	.98	.98
3	Fifth Grade Speech[1]			.99	.98	.98	.98	.98
4	Adult Speech[1]				.97	.98	.98	.98
5	Adult Text[2]					.98	.98	.98
6	First Reader[3]						.99	.98
7	Third Reader[3]							.996
8	Fifth Reader[3]							

[1] Our own tape recordings, letter transcriptions

[2] Dewey, 1923 (In Reza, 1961)

[3] Ginn Basic Readers

TABLE 3

Relative Sequential Constraint in Ginn Series Readers.

	1st Reader	2nd Reader	3rd Reader	5th Reader
C_2	.241	.233	.221	.213
C_3	.368	.351	.322	.303
C_4	.427	.413	.363	.339
C_5	.464	.444	.385	.356
C_6	.483	.460	.396	.365
C_7	.496	.471	.403	.370
C_8	.505	.478	.407	.374
C_9	.511	.482	.410	.376
C_{10}	.515	.485	.412	.377
C_{11}*	.518	.486	.414	.377
Mean Word Length	3.665	3.748	3.997	4.106
Mean Sentence Length	6.716	7.754	10.617	12.095
H (1)	4.105	4.125	4.131	4.113
Sample Size (No. of words)	10295.	12662.	10808.	12422.

* C_{11} x 100 approximates the usual measure of percent redundancy.

TABLE 4

Relative Sequential Constraint in Allyn and Bacon Series Readers.

	1st Grade	3rd Grade	5th Grade
C_2	.235	.208	.214
C_3	.358	.306	.305
C_4	.416	.349	.345
C_5	.446	.371	.364
C_6	.463	.381	.373
C_7	.474	.388	.378
C_8	.480	.393	.382
C_9	.485	.396	.384
C_{10}	.488	.398	.386
C_{11}*	.490	.400	.387
Mean Word Length	3.736	3.987	4.188
Mean Sentence Length	7.266	9.822	12.038
H (1)	4.094	4.119	4.117
Sample Size (No. of words)	9438.	12768.	12291.

* C_{11} x 100 approximates the usual measure of percent redundancy.

TABLE 5

Comparison of Adult and Child Reading Material in Terms of Information, Constraint, and Mean Word Length.

Source	C_2	C_{11}††	Mean Word Length	Number of Letters in Sample	H(1)
Atlantic Monthly*	.184	.319	4.653	10,000	4.152
William James*	.192	.361	4.556	10,000	4.121
5th Reader	.213	.378	4.106	64,454	4.113
3rd Reader	.221	.414	3.997	55,027	4.131
Bible	.216	.429	4.014	10,601	4.049
2nd Reader	.233	.486	3.748	61,759	4.125
1st Reader	.241	.518	3.665	49,556	4.105
Russian Bible*	.245	.472	5.296	10,000	4.549
Russian Phonemes†	.232	----	-----	9,000	4.780

* Computed from data of Newman and Waugh.

† Computed from data of Jakobson, Cherry and Halle.

†† C_{11} x 100 gives the usual measure of percent redundancy.

TABLE 6

Relative Sequential Constraint in Free Reading Choices.

	Level 1	Level 3	Level 5
C_2	.217	.209	.206
C_3	.313	.302	.298
C_4	.358	.337	.336
C_5	.382	.355	.355
C_6	.396	.363	.364
C_7	.406	.368	.370
C_8	.414	.372	.373
C_9	.419	.373	.376
C_{10}	.422	.375	.377
C_{11}*	.425	.376	.379
Mean Word Length	4.120	3.992	4.029
Mean Sentence Length	10.142	12.222	16.481
H (1)	4.133	4.091	4.100
Sample Size (No. of words)	12384.	11440.	14981.

* C_{11} x 100 approximates the usual measure of percent redundancy.

TABLE 7

Relative Sequential Constraint in Free Reading Choices
Effect of Sample Size**

	1400 words	3000 words	6000 words	12000 words	18000 words
C_2	.202	.204	.204	.206	.207
C_3	.288	.291	.291	.298	.297
C_4	.327	.327	.327	.336	.335
C_5	.346	.344	.344	.353	.353
C_6	.355	.352	.352	.362	.362
C_7	.362	.358	.358	.367	.367
C_8	.364	.360	.360	.370	.370
C_9	.366	.362	.362	.372	.372
C_{10}	.366	.363	.364	.373	.373
C_{11}*	.366	.363	.365	.374	.374
Mean Word Length	4.037	3.991	3.977	3.998	4.006
Mean Sentence Length	17.885	16.062	17.597	17.116	18.054
H (1)	4.091	4.086	4.083	4.089	4.090
Sample Size (No. of words)	1395.	2859.	5719.	11314.	18000.

* C_{11} x 100 approximates the usual measure of percent redundancy

** Alice in Wonderland - random sample.

TABLE 8

Relative Sequential Constraint in Three Third-level Texts.

	The Courage of Sarah Noble	Winnie the Pooh	The Emperor's New Clothes
C_2	.219	.208	.224
C_3	.325	.308	.329
C_4	.372	.351	.376
C_5	.396	.373	.407
C_6	.410	.378	.422
C_7	.418	.390	.434
C_8	.423	.395	.441
C_9	.426	.398	.444
C_{10}	.428	.400	.445
C_{11}*	.430	.403	.446
Mean Word Length	4.023	3.979	4.198
Mean Sentence Length	10.430	11.976	19.313
H (1)	4.082	4.117	4.071
Sample Size (No. of words)	6748.	21462.	1970.

* C_{11} x 100 approximates the usual measure of percent redundancy.

TABLE 9

Relative Sequential Constraint in Three Fifth-level Texts.

	Dr. Doolittle	Mary Poppins	Alice in Wonderland
C_2	.217	.210	.207
C_3	.322	.308	.297
C_4	.368	.352	.335
C_5	.394	.375	.353
C_6	.407	.388	.362
C_7	.415	.397	.367
C_8	.420	.404	.370
C_9	.424	.409	.372
C_{10}	.426	.412	.373
C_{11}*	.428	.415	.374
Mean Word Length	3.966	4.150	4.006
Mean Sentence Length	15.384	14.454	18.054
H (1)	4.087	4.140	4.090
Sample Size (No. of words)	8246.	9930.	18000.

* C_{11} x 100 approximates the usual measure of percent redundancy.

TABLE 10

Relative Sequential Constraint in the Letter and Phoneme Transcriptions: 1, 3, and 5 Grade and Adult Speech.

	Grade 1		Grade 3		Grade 5		Adult	
	Letter	Phoneme	Letter	Phoneme	Letter	Phoneme	Letter	Phoneme
C_2	.211	.192	.208	.189	.201	.191	.198	.196
C_3	.305	.257	.303	.252	.295	.255	.291	.254
C_4	.345	.280	.342	.274	.333	.276	.328	.286
C_5	.366	.289	.363	.280	.353	.283	.348	.294
C_6	.374	.293	.372	.284	.362	.286	.357	.298
C_7	.381	.296	.378	.286	.367	.288	.363	.299
C_8	.384	.297	.382	.287	.371	.289	.366	.300
C_9	.387	.298	.384	.287	.373	.289	.368	.300
C_{10}	.388	.299	.386	.288	.374	.290	.370	.300
C_{11}*	.389	.299	.387	.288	.375	.290	.370	.300
Mean Word Length	3.632	10.631	3.653	10.579	3.754	11.276	3.903	11.765
Mean Sentence Length	10.040	2.746	11.538	3.212	10.477	2.772	9.705	2.540
H (1)	4.083	4.834	4.084	4.842	4.104	4.872	4.124	4.882
Sample Size (No. of characters)	94,767.	66,179.	101,285.	70,842.	131,274.	90,741	78,580.	54,478.

* C_{11} x 100 approximates the usual measure of percent redundancy.

TABLE 11

Mean Word Length for Two Series of Graded Readers, Free-reading Choices, and Letter Transcription of Speech at Four Levels.

	First Grade	Third Grade	Fifth Grade	Adult
Ginn	3.7	4.0	4.1	-
Allyn and Bacon	3.7	4.0	4.2	-
Free-reading Choices	4.1	4.0	4.0	-
Letter Transcriptions	3.6	3.6	3.8	3.9

TABLE 12

Mean Sentence Length for Two Series of Graded Readers, Free-reading Choices, and Letter Transcriptions of Speech at Four Levels.

	First Grade	Third Grade	Fifth Grade	Adult
Ginn	6.7	10.6	12.1	-
Allyn and Bacon	7.3	9.8	12.0	-
Free-reading Choices	10.1	12.2	16.5	-
Letter Transcriptions	10.0	11.5	10.5	9.7

TABLE 13

Proportions, p, of Letters in Natural Speech.

of 1st Grade			of 3rd Grade			of 5th Grade			of Adults		
letters	f	p	letters	f	p	letters	f	p	letters	f	p
e	8683	.11936	e	9180	.11759	e	12273	.12077	e	7109	.11603
t	7032	.09667	t	7362	.09430	t	9693	.09538	t	6150	.10037
a	5987	.08230	a	6376	.08167	o	8329	.08196	o	5390	.08797
o	5886	.08092	o	6362	.08149	a	8211	.08080	a	4652	.07592
n	5213	.07166	h	5552	.07112	h	7139	.07025	i	4271	.06971
h	5089	.06996	n	5536	.07091	n	6791	.06682	h	4062	.06630
i	4706	.06469	i	5007	.06414	i	6375	.06273	n	3952	.06450
s	4190	.05760	s	4663	.05973	s	6290	.06189	s	3394	.05539
d	3289	.04521	d	3613	.04628	r	4517	.04445	r	2870	.04684
r	3039	.04178	r	3406	.04363	d	4371	.04301	l	2520	.04113
m	2623	.03606	u	2842	.03640	u	3679	.03620	u	2418	.03946
u	2451	.03369	l	2705	.03465	l	3611	.03553	d	2213	.03612
l	2431	.03342	w	2511	.03216	y	3179	.03146	y	2210	.03607
w	2301	.03163	m	2362	.03026	w	3111	.03061	w	1780	.02905
y	2119	.02913	y	2253	.02886	m	2623	.02581	g	1482	.02419
g	1721	.02366	g	1740	.02229	g	2381	.02343	m	1196	.01952
c	1312	.01804	c	1407	.01802	c	1868	.01838	c	1181	.01928
b	1214	.01669	b	1236	.01583	k	1574	.01549	b	912	.01488
f	955	.01313	k	1197	.01533	b	1537	.01512	f	885	.01444
k	892	.01226	f	1005	.01287	f	1406	.01384	k	860	.01404
p	809	.01112	p	968	.01240	p	1293	.01272	p	804	.01312
v	530	.00729	v	533	.00683	v	925	.00910	v	627	.01023
j	137	.00188	j	159	.00204	j	237	.00233	j	206	.00336
x	90	.00124	x	52	.00067	x	101	.00099	x	71	.00116
q	24	.00033	z	23	.00030	z	58	.00057	z	31	.00051
z	19	.00026	q	15	.00019	q	28	.00028	q	23	.00038
Total 72,742			Total 78,065			Total 101,618			Total 61,269		

TABLE 14

Proportions, p, of Phonemes in Natural Speech.

of 1st Graders						of 3rd Graders					
Vowels			Consonants			Vowels			Consonants		
	f	p		f	p		f	p		f	p
ə	7490	.12770	n	4791	.08168	ə	8064	.12794	n	5095	.08083
i	2615	.04458	r	2884	.04917	i	2884	.04576	r	3305	.05243
iy	2235	.03810	t	2783	.04745	iy	2502	.03969	t	2943	.04669
ae	1900	.03239	m	2633	.04489	ae	1933	.03067	s	2831	.04491
e	1725	.02941	s	2438	.04157	e	1914	.03037	d	2473	.03923
ow	1196	.02039	d	2218	.03782	ow	1383	.02194	m	2383	.03781
ey	976	.01664	w	1959	.03340	ey	1020	.01618	w	1976	.03135
a	900	.01534	l	1745	.02975	a	976	.01548	l	1910	.03030
ɔ	843	.01437	k	1648	.02810	ɔ	875	.01388	ʔ	1862	.02954
uw	711	.01212	z	1609	.02743	uw	785	.01245	k	1802	.02859
u	244	.00416	ʔ	1580	.02694	u	314	.00498	ð	1729	.02743
			ð	1553	.02648				z	1619	.02568
			h	1186	.02022				b	1184	.01878
			b	1117	.01904				h	1162	.01844
ay	2179	.03715	g	1021	.01741	ay	1997	.03168	g	953	.01512
aw	451	.00769	f	776	.01323	aw	477	.00757	p	887	.01407
ɔy	35	.00060	p	747	.01274	ɔy	50	.00079	f	827	.01312
Total Vowels	20,835	.35523	v	576	.00982	Total Vowels	22,650	.35936	y	713	.01131
			y	496	.00846				v	599	.00950
			ŋ	368	.00627				ŋ	450	.00714
			θ	363	.00619				θ	363	.00576
			š	296	.00505				š	356	.00565
			ǰ	187	.00319				č	217	.00344
			č	179	.00305				ǰ	216	.00343
			ž	0	0				ž	0	0
			Total Consonants	35,153	.59933				Total Consonants	37,855	.60060

TABLE 14 (continued)

Proportions, p, of Phonemes in Natural Speech.

of 5th Graders						of Adults					
Vowels			Consonants			Vowels			Consonants		
	f	p		f	p		f	p		f	p
ə	10593	.13082	n	6118	.07556	ə	6325	.12985	n	3464	.07112
i	3693	.04561	r	4379	.05408	i	2489	.05110	r	2806	.05761
iy	3348	.04135	t	3738	.04616	iy	1835	.03767	s	2264	.04648
e	2463	.03042	s	3549	.04383	e	1551	.03184	t	2248	.04615
ae	2209	.02728	d	3309	.04087	ae	1229	.02523	l	1850	.03798
ow	1823	.02251	m	2637	.03257	ow	1139	.02338	d	1827	.03751
ey	1359	.01678	l	2591	.03200	uw	869	.01784	k	1414	.02903
a	1330	.01643	w	2451	.03027	ey	755	.01550	w	1397	.02868
ɔ	1163	.01436	k	2342	.02892	ɔ	737	.01513	ɚ	1354	.02780
uw	1079	.01333	z	2243	.02770	a	596	.01224	m	1199	.02462
u	418	.00516	ɚ	2198	.02714	u	230	.00472	z	1107	.02273
			ʔ	1772	.02188				ʔ	988	.02028
			h	1478	.01825				y	941	.01932
			b	1430	.01766				b	877	.01800
			g	1245	.01538				h	793	.01628
ay	2261	.02792	y	1228	.01517	ay	1555	.03192	v	738	.01515
aw	578	.00714	p	1211	.01496	aw	367	.00753	p	694	.01425
ɔy	74	.00091	f	1115	.01377	ɔy	43	.00088	f	692	.01421
Total Vowels	29,478	.36406	v	1030	.01272	Total Vowels	17,755	.36451	g	598	.01228
			ŋ	668	.00825				ŋ	516	.01059
			š	647	.00799				ǰ	397	.00815
			θ	505	.00624				θ	388	.00796
			č	360	.00445				š	221	.00454
			ǰ	335	.00414				č	215	.00441
			ž	0	0				ž	0	0
			Total Consonants	48,579	.59996				Total Consonants	28,988	.59514

TABLE 15

Rank Order of Vowel and Consonant Phonemes by Frequency of Occurrence for First, Third, Fifth Graders and Adults.

A. Vowels

Rank	1st	3rd	5th	Adult	Denes*
1	ə (the)	ə	ə	ə	ə
2	i (hit)	i	i	i	i
3	iy (beat)	iy	iy	iy	ay
4	æ (bat)	æ	e	e	e
5	e (bet)	e	æ	æ	iy
6	ow (boat)	ow	ow	ow	ow
7	ey (may)	ey	ey	uw	ʌ
8	a (pot)	a	a	ey	ɔ
9	ɔ (bought)	ɔ	ɔ	ɔ	a
10	uw (boot)	uw	uw	a	ey
11	u (put)	u	u	u	uw

* = rank according to Denes (1963)

TABLE 15 (continued)

Rank Order of Vowel and Consonant Phonemes by Frequency of Occurrence for First, Third, Fifth Graders and Adults.

B. Consonants

Rank	1st	3rd	5th	Adult	Denes*
1	n	n	n	n	t
2	r	r	r	r	n
3	t	t	t	s	s
4	m	s	s	t	d
5	s	d	d	l	l
6	d	m	m	d	m
7	w	w	l	k	ð
8	l	l	w	w	k
9	k	ʔ	k	ð	r
10	z	k	z	m	w
11	ʔ	ð	ð	z	z
12	ð	z	ʔ	ʔ	b
13	h	b	h	y	v
14	b	h	b	b	p
15	g	g	g	h	f
16	f	p	y	v	h
17	p	f	p	p	j
18	v	y	f	f	ŋ
19	y	v	v	g	g
20	ŋ	ŋ	ŋ	ŋ	ʃ
21	θ	θ	š	ǰ	θ
22	š	š	θ	θ	ǰ
23	ǰ	č	č	š	š
24	č	ǰ	ǰ	č	ž
25	ž	ž	ž	ž	

* = rank according to Denes (1963)

TABLE 16A

Frequency of Occurrence of Phonemes in Natural Speech of First Graders.

		Frequency	Proportion
Vowels			
I	Front (i,iy,e,ey,ae)	9451	.16113
	Central (ə,a)	8390	.14305
	Back (u,uw,ow,ɔ)	2994	.05105
		20835	.35523
II	Closed (iy,i,u,uw,e,cy,cw)	9702	.16541
	Open (ae,a,ɔ,ə)	11133	.18982
		20835	.35523
Consonants			
I	State of Glottis		
	Voiceless (p,t,č,k,ʔ,f,θ,s,š,h)	11996	.20452
	Voiced (b,d,ǰ,g,v,ð,z,ž,m,n,ŋ,l,r,y,w)	23157	.39481
		35153	.59933
II	Manner of Articulation		
	Stops (p,t,č,k,ʔ,b,d,ǰ,g)	11480	.19573
	Fricatives (f,θ,s,š,h,v,ð,z,ž)	8797	.14998
	Nasals (m,n,ŋ)	7792	.13285
	Approximants (l,r,y,w)	7084	.12078
		35153	.59934
III	Place of Articulation		
	Bilabial (p,b,m)	4497	.07667
	Labio-dental (f,v,θ,ð)	3268	.05572
	Dental-alveolar (t,d,s,z,n,l)	15584	.26570
	Post-alveolar (š,ž,č,ǰ)	662	.01129
	Retroflex (r)	2884	.04917
	Velar (k,g,ŋ)	3037	.05178

TABLE 16A (continued)

		Frequency	Proportion
	Labio-velar (w)	1959	.03340
	Glottal (h, ʔ)	2766	.04716
		34657	.59089
IV	Diphthongs		
	ɔy	35	.00060
	aw	451	.00769
	ay	2179	.03715
		2665	.04544
V	Grand Total		
	Vowels	20835	.35523
	Consonants	35153	.59933
	Diphthongs	2665	.04544
		58653	1.00000

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Office of Education
Cooperative Research Branch

Project Description

Objectives. (1) To measure the amount of redundancy of children's written and spoken language, and of that written for and spoken to them. (2) Using experimental material quantified with respect to redundancy or patterning, to determine its influence on learning, retention, comprehension, reading, and other language behavior. (3) Based on the outcome of these experiments, to write one or more texts in which redundancy is well-defined. These constructed texts will be used in experiments with new groups of children to test the hypothesis that language development is fastest when optimal redundancy is built into the texts.

Procedure. Samples of reading materials and spoken language will be collected that are appropriate to children in the second, fourth, and sixth grades. These samples will be quantified in terms of a measure of redundancy, and statistical comparisons will be made with similar measures obtained for adult language. Using these measures, learning materials will be constructed at five redundancy levels to investigate the influence of redundancy upon learning. A simple factorial analysis of variance design will permit a quantitative evaluation of the effect of the variables on the learning measure, including interactions and linearity.

TABLE 16B

Frequency of Occurrence of Phonemes in Natural Speech of Third Graders.

		Frequency	Proportion
Vowels			
I	Front (i,iy,e,ey,ae)	10253	.16267
	Central (ə,a)	9040	.14343
	Back (u,uw,ow,ɔ)	3357	.05326
		22650	.35936
II	Close (i,iy,u,uw,e,ey,ow)	10802	.17138
	Open (ae,a,ɔ,ə)	11848	.18798
		22650	.35936
Consonants			
I	State of Glottis		
	Voiceless (p,t,č,k,ʔ,f,θ,s,š,h)	13250	.21022
	Voiced (b,d,ǰ,g,v,ð,z,ž,m,n,ŋ,l, r,y,w)	24605	.39038
		37855	.60060
II	Manner of Articulation		
	Stops (p,t,č,k,ʔ,b,d,ǰ,g)	12537	.19891
	Fricatives (f,θ,s,š,h,v,ð,z,ž)	9486	.15050
	Nasals (m,n,ŋ)	7928	.12578
	Approximants (l,r,y,w)	7904	.12540
		37855	.60059
III	Place of Articulation		
	Bilabial (p,b,m)	4454	.07067
	Labio-dental (f,v,θ,ð)	3518	.05582
	Dental-alveolar (t,d,s,z,n,l)	16871	.26767
	Post-alveolar (š,ž,č,ǰ)	789	.01252

TABLE 16B (continued)

		Frequency	Proportion
	Retroflex (r)	3305	.05244
	Velar (k,g,ŋ)	3205	.05085
	Labio-velar (w)	1976	.03135
	Glottal (h,ʔ)	3024	.04798
		37142	.58930
IV	Diphthongs		
	ɔy	50	.00079
	aw	477	.00757
	ay	1997	.03168
		2524	.04004
V	Grand Total		
	Vowels	22650	.35936
	Consonants	37855	.60060
	Diphthongs	2524	.04004
		63029	1.00000

TABLE 10C

Frequency of Occurrence of Phonemes in Natural Speech of Fifth Graders.

		Frequency	Proportion
Vowels			
I	Front (i,iy,e,ey,ae)	13072	.16144
	Central (ə,a)	11923	.14725
	Back (u,uw,ow,ɔ)	4483	.05537
		29478	.36406
II	Closed (iy,i,u,uw,e,ey,ow)	14183	.17516
	Open (ae,a,ɔ,ə)	15295	.18890
		29478	.36406
Consonants			
I	State of Glottis		
	Voiceless (p,t,č,k,ʔ,f,θ,s,š,h)	16717	.20646
	Voiced (b,d,ǰ,g,v,ð,z,ž,m,n,ŋ, l,r,y,w)	31862	.39350
		48579	.59996
II	Manner of Articulation		
	Stops (p,t,č,k,ʔ,b,d,ǰ,g)	15742	.19442
	Fricatives (f,θ,s,š,h,v,ð,z,ž)	12765	.15765
	Nasals (m,n,ŋ)	9423	.11638
	Approximants (l,r,y,w)	10649	.13152
		48579	.59997
III	Place of Articulation		
	Bilabial (p,b,m)	5278	.06519
	Labio-dental (f,v,θ ð)	4848	.05987
	Dental-alveolar (t,d,s,z,n,l)	21548	.26612
	Post-alveolar (š,ž,č,ǰ)	1342	.01657

TABLE 16C (continued)

		Frequency	Proportion
	Retroflex (r)	4379	.05408
	Velar (k,g,ŋ)	4255	.05255
	Labio-velar (w)	2451	.03027
	Glottal (h,ʔ)	3250	.04014
		47351	.58479
IV	Diphthongs		
	ɔy	74	.00091
	aw	578	.00714
	ay	2261	.02792
		2913	.03597
V	Grand Total		
	Vowels	29478	.36406
	Consonants	48579	.59996
	Diphthongs	2913	.03598
		80970	1.00000

TABLE 16D

Frequency of Occurrence of Phonemes in Natural Speech of Adults.

	Vowels	Frequency	Proportion
I	Front (i,iy,e,ey,ae)	7859	.16134
	Central (ʌ,a)	6921	.14210
	Back (u,uw,ow,ɔ)	2975	.06107
		17755	.36451
II	Close (i,iy,u,uw,e,ey,ow)	8868	.18205
	Open (ae,a,ɔ,ə)	8887	.18246
		17755	.36451
	Consonants		
I	State of Glottis		
	Voiceless (p,t,č,k,ʔ,f,θ,s,š,h)	9917	.20360
	Voiced (b,d,ǰ,g,v,ð,z,ž,m,n,ŋ,l, r,y,w)	19071	.39154
		28988	.59514
II	Manner of Articulation		
	Stops (p,t,č,k,ʔ,b,d,ǰ,g)	9258	.19006
	Fricatives (f,θ,s,š,h,v,ð,z,ž)	7557	.15516
	Nasals (m,n,ŋ)	5179	.10633
	Approximants (l,r,y,w)	6994	.14359
		28988	.59514
III	Place of Articulation		
	Bilabial (p,b,m)	2770	.05688
	Labio-dental (f,v,θ,ð)	3172	.06513
	Dental-alveolar (t,d,s,z,n,l)	10089	.20713
	Post-alveolar (š,ž,č,ǰ)	833	.01710
	Retroflex (r)	2806	.05761

TABLE 16D (continued)

		Frequency	Proportion
	Velar (k,g,ŋ)	2528	.05190
	Labio-velar (w)	1397	.02868
	Glottal (h,ʔ)	1781	.03656
		25376	.52099
IV	Diphthongs		
	ɔy	43	.00088
	aw	367	.00754
	ay	1555	.03193
		1965	.04035
V	Grand Total		
	Vowels	17755	.36451
	Consonants	28988	.59514
	Diphthongs	1965	.04035
		48708	1.00000

TABLE 17

Product-moment Correlation Matrix for 22 Consonant Phonemes from 15 Sets of Data.[1]

										Natural Speech				
										First	Third	Fifth	Adult	Hultzén
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
THN	1	.58	.42	.75	.67	.73	.75	.72	.72	.71	.63	.66	.68	.71	.41
POW	2		.92	.83	.80	.81	.82	.86	.74	.82	.76	.80	.83	.86	.92
CAR	3			.63	.56	.58	.62	.71	.54	.72	.60	.62	.64	.66	.999
HAY	4				.95	.98	.97	.97	.88	.88	.89	.91	.93	.94	.62
WHI	5					.98	.97	.92	.86	.80	.88	.91	.93	.94	.56
DEW	6						.98	.96	.90	.87	.89	.91	.94	.94	.58
VOE	7							.96	.91	.88	.91	.93	.95	.96	.62
FRE	8								.89	.94	.89	.90	.92	.93	.71
FRY	9									.90	.90	.92	.92	.90	.55
TOB	10										.81	.81	.83	.82	.72
1st	11											.99	.98	.93	.60
3rd	12												.99	.96	.62
5th	13													.98	.64
A	14														.66

---

[1] Sample sources: 1, dictionary; 2, modern prose; 3, modern plays; 4, lectures; 5, modern prose; 6, newspapers; 7, radio announcements; 8, telephone conversations; 9, phonetic readers; 10, telephone conversations; 11, 12, 13, 14, phonemic transcriptions of our own data; 15, modern plays (same data as CAR, 3). See discussion in text for details.

TABLE 18

Pilot Serial Learning Task

Trigrams Which Are Words[1]

Child

Visual Presentation.[2]

		Frequency			
Grade	**N**	**Hi**	**Med**	**Lo**	**Mean**
1	4	9.9	13.6	13.0	12.2
5	4	2.8	3.0	3.5	3.1

Freq. = some effect

Grade = strong effect

[1] Score = Av. trial upon which words of the freq. class were learned. R = saying the words. Anticipation. 6 items. Frequency is the trigram frequency (Pratt count).

[2] For 1st graders, prompting was necessary, thus confounding the visual and auditory modalities and rendering this task useless at this level.

TABLE 19

Pilot Serial Learning Task - Words[1]

Child

			Frequency			
Grade	Modality	N	Hi	Med	Lo	Mean
1	Vis.	2*	16.3	17.5	17.3	17.0
	Aud.	6	15.2	14.7	16.0	15.3
3	Vis.	5	8.7	7.5	8.5	8.2
	Aud.	6	5.9	4.9	6.2	5.7
5	Vis.	4	9.0	13.0	8.5	10.2
	Aud.	6	3.3	3.9	3.9	3.7

Freq. = no effect
Grade = strong effect
Modality = strong effect (auditory = much easier at all grade and frequency levels)

[1] Score = Av. trial upon which words of freq. class were learned. R = saying the letters. Anticipation. Frequency is the word frequency (T-L count).

*4 add. 1st graders could not learn task.

TABLE 20

Pilot Serial Learning Task - Words[1]

Adult

			Frequency			
Modality	N, S's	N, Lists	Hi	Med	Lo	Total
Visual	8	24	44	46	42	132
Auditory	8	24	136	138	181	455

Source	df	MS	F	P<
Modality	1	6520.5	10.13	.01
Error	14	643.6		

---

[1] List = 9 trigrams which are words. R = say word (4 lists used - each S = 3)

[2] Criterion = 3 consecutive errorless trials. Score = No. of errors.

[3] Visual modality much easier than auditory.

TABLE 21

Pilot Short-term Retention

Words

			Frequency								
	N	Delay (Sec.)	Hi			Med			Lo		
			0	3	6	0	3	6	0	3	6
Grade 1	4	Aud.	3.0	1.0	0.5	3.0	1.25	1.0	2.5	1.0	0.5
	6	Vis.	2.2	1.2	0.5	2.2	0.67	0.33	2.7	0.5	0.17
Grade 3	3	Aud.	3.0	1.7	0.7	3.0	2.7	1.7	3.0	2.3	0.3
	4	Vis.	3.0	1.75	0.5	2.8	1.5	1.5	3.0	1.0	0.25
Grade 5	4	Aud.	3.0	1.8	0.2	3.0	1.2	0.5	3.0	1.8	0.8
	2	Vis.	3.0	2.0	1.5	3.0	3.0	0.25	2.0	2.0	0.5
Mean	11	Aud.	3.0	1.5	.5	3.0	2.05	1.1	2.8	1.7	.5
	12	Vis.	2.7	1.65	.8	2.7	1.72	.69	2.9	1.2	.3

Max. score/cell = 3.0.
Score = Mean No. correct.

TABLE 22

Pilot Short-term Retention Task[1]

Meaningless Trigrams

Visual (Say Letters)

Grade	Material	N	Frequency								
Delay (sec.)			Hi			Med			Lo		
			0	3	6	0	3	6	0	3	6
1	Meaningless Trigrams	4	1.5	1.8	0	2.0	.50	0	3.0	.75	.75
3	Meaningless Trigrams	5	2.6	1.2	.40	3.0	.60	.40	2.8	.60	1.0
5	Meaningless Trigrams	2	3.0	1.5	1.0	3.0	1.0	1.5	3.0	2.0	.5

[1] Score = No. correct (max. possible in each cell = 3.0).

TABLE 23

Pilot Narrative Materials: I - Auditory[1]

Adult S's

		Redundancy Level[2]		
S/N	N	1	3	5
100	4	1219	1166	1203
25	4	1151	1084	1083
20	4	1046	968	950
15	4	837	698	607
10	4	264	270	256
Total	20	4517	4186	4099

Anova: Signal-to-Noise Ratio: F = 102.3**, df = 4

Redundancy: F = 18.9**, df = 2

N x R: F = 4.2**, df = 8

$P < .01$

---

[1] Score is No. of words correctly recalled.

[2] 90 sentences chosen randomly from Ginn Readers, 3 lengths:
Short = 3-5 words
Med = 9-11 words
Long = 15-20 words

TABLE 24

Pilot Narrative Materials: II - Auditory[1]

Adult S's

		Redendancy Level[2]		
S/N	N	1	3	5
100	4	581	605	594
25	4	487	483	468
20	4	347	287	331
15	4	79	131	112
10	4	1	2	2
Total	20	1495	1508	1507

No statistical test necessary. There is no redundancy effect here. S/N is obviously very significant.

---

[1] Score is No. of words correctly recalled (about 600 is perfect).

[2] 50 sentences chosen at random from free-choice reading at levels 1, 3, and 5; med. length sentences (9-11 words) only.

TABLE 25

Pilot Recognition Task - First Grade

	Visual Presentation					Auditory Presentation				
	N	High Freq.	Low Freq.	Non-Words	Total	N	High Freq.	Low Freq.	Non-Words	Total
List 1 (Revised)										
"New" Errors	5	56	62	61	179	5	32	61	56	149
False Alarms		61	57	63	181		77	81	78	236
List 3										
"New" Errors	5	42	44	52	138	5	53	61	56	170
False Alarms		76	67	61	204		46	63	47	156

Analysis of Variance for "New" Errors

Source (Significant only)	df	*F*	*p*<
Frequency	2,32	4.69	.05
High Freq. Words vs. Mean of Low Freq. Words and Non-Words	1,32	9.34	.01

Analysis of Variance for False Alarms

Source (Significant only)	df	*F*	*p*<
M x L	1,84	10.61	.01
F x M	2,84	4.63	.05

TABLE 26

Pilot Recognition Task - Third Grade

	Visual Presentation					Auditory Presentation				
	N	High Freq.	Low Freq.	Non-Words	Total	N	High Freq.	Low Freq.	Non-Words	Total
List 1 (Revised)										
"New" Errors	5	18	19	27	64	5	23	28	34	85
False Alarms		65	58	55	178		31	52	38	121
List 3										
"New" Errors	5	17	23	33	73	5	23	22	49	94
False Alarms		44	35	34	113		34	39	33	106

Analysis of Variance for "New" Errors

Source (Significant only)	df	F	p<
Frequency	2,32	8.68	.01
Delay	4,64	4.69	.01
F x M	2,64	10.46	.01
F x D x M	8,128	2.08	.05
Non-Words vs. Low Frequency Words	1,32	4.64	.05
Non-Words vs. Words	1,32	7.60	.01

Analysis of Variance for False Alarms

Source (Significant only)	df	F	p<
Modality	1,64	7.51	.01
List	1,64	11.73	.01
M x L	1,64	4.58	.05

TABLE 27

Pilot Recognition Task - Fifth Grade

	Visual Presentation					Auditory Presentation				
	N	High Freq.	Low Freq.	Non-Words	Total	N	High Freq.	Low Freq.	Non-Words	Total
List 1 (Revised)										
"New" Errors	5	12	26	30	68	5	15	10	24	49
False Alarms		36	41	29	106		28	39	32	99
List 3										
"New" Errors	5	3	15	25	43	5	27	26	39	92
False Alarms		47	43	26	116		37	51	31	119

Analysis of Variance for "New" Errors

Source (Significant only)	df	F	p<
H x L	1,16	6.04	.05
Frequency	2,32	13.01	.01
Delay	4,64	4.47	.01
F x H	2,32	3.70	.05
Low Frequency Words vs. Non-Words	1,32	12.01	.01
Words vs. Non-Words	1,32	23.40	.01

Analysis of Variance for False Alarms

Source (Significant only)	df	F	p<
List	1,64	5.26	.05
Frequency	2,64	26.53	.01
F x H	2,64	7.07	.01
F x L	2,64	5.27	.01

TABLE 25

Pilot Recognition Task - Adults

	Visual Presentation					Auditory Presentation				
	N	High Freq.	Low Freq.	Non-Words	Total	N	High Freq.	Low Freq.	Non-Words	Total
List 1 (Revised)										
"Yes" Errors	10	22	19	42	83					
False Alarms		38	40	26	104					
List 1										
"Yes" Errors						10	24	27	33	84
False Alarms							28	32	35	95

Analysis of Variance for "Yes" Errors

Source (Significant only)	df	F	$p<$
Modality	1,108	17.05	.01
Frequency	2,108	3.52	.05
F x D	6,108	2.37	.05
Words vs. Non-Words	1,108	6.66	.05
Words vs. Non-Words (Vision only)	1,135	12.46	.01

Analysis of Variance for False Alarms

Source (Significant only)	df	F	$p<$
Modality	1,108	5.22	.05

Analysis of Variance for False Alarms for all 5 Delay Categories for Audition and Vision Separately

		df	F	$p<$
Vision	Delay	4,135	4.30	.01
	F x D	8,135	3.75	.01
	Words vs. Non-Words	1,135	4.53	.05

		df	F	$p<$
Audition	Delay	4,135	13.34	.01
	F x D	8,135	4.86	.01

TABLE 29

Analysis of Variance, Main Recognition Experiment,
Based on Each S's Total Number of "New" Errors
(i.e., S said "new" to an old item), for all 256 Ss.

Source of Variation	df	Mean Square	F	p
Between Ss				
Modality[1] (M)	1	[illegible]	[illegible]	<.001
School (S)	1	[illegible]	[illegible]	<.005
Reading Level (R)	3	[illegible]	[illegible]	<.001
List (L)	3	[illegible]	[illegible]	ns*
M x S	1	[illegible]	[illegible]	ns
M x R	3	[illegible]	[illegible]	ns
M x L	3	[illegible]	[illegible]	ns
S x R	3	[illegible]	[illegible]	ns
S x L	3	[illegible]	[illegible]	ns
R x L	9	[illegible]	[illegible]	ns
M x S x R	3	[illegible]	[illegible]	ns
M x S x L	3	[illegible]	[illegible]	ns
M x R x L	9	[illegible]	[illegible]	ns
S x R x L	9	[illegible]	[illegible]	ns
M x S x R x L	9	[illegible]	[illegible]	ns
Error (between)	192	[illegible]		
Within S				
Frequency (F)	2	[illegible]	[illegible]	<.001
M x F	2	[illegible]	[illegible]	<.005
S x F	2	[illegible]	[illegible]	ns
R x F	6	[illegible]	[illegible]	<.05
L x F	6	[illegible]	[illegible]	ns
M x S x F	2	[illegible]	[illegible]	ns
M x R x F	6	[illegible]	[illegible]	ns
M x L x F	6	[illegible]	[illegible]	ns
S x R x F	6	[illegible]	[illegible]	ns
S x L x F	6	[illegible]	[illegible]	ns
R x L x F	18	[illegible]	[illegible]	ns
M x S x R x F	6	[illegible]	[illegible]	ns
M x S x L x F	6	[illegible]	[illegible]	ns
M x R x L x F	18	[illegible]	[illegible]	ns
S x R x L x F	18	[illegible]	[illegible]	ns
M x S x R x L x F	18	[illegible]	[illegible]	ns
Error (within)	384	[illegible]		

*ns = not significant, with $p\,[F(v_1, v_2)] > .05$

[1] For the purpose of carrying out the analysis on the complete experiment, the 64 Adults (R 1) were randomly assigned to the two schools, half to one, and half to the other.

TABLE 30

Analysis of Variance, Main Recognition Experiment, Based on Each S's Total Number of False Alarm Errors (i.e., S said "old" to a new item), for all 256 Ss.

Source of Variation	df	Mean Square	F	p
Between Ss				
Modality[1] (M)	1	160.40	7.17	<.025
School (S)	1	10.44	0.47	ns*
Reading Level (R)	3	1049.33	46.43	<.001
List (L)	3	170.38	7.62	<.01
M x S	1	0.03	0.00	ns
M x R	3	42.70	1.91	ns
M x L	3	1.90	0.08	ns
S x R	3	7.10	0.32	ns
S x L	3	6.36	0.28	ns
R x L	9	41.10	1.84	ns
M x S x R	3	17.73	0.79	ns
M x S x L	3	3.40	0.15	ns
M x R x L	9	4.30	0.19	ns
S x R x L	9	30.07	1.34	ns
M x S x R x L	9	15.05	0.67	ns
Error (between)	192	22.37		
Within S				
Frequency (F)	4	375.38	61.87	<.001
M x F	4	43.61	7.20	<.001
S x F	4	9.40	1.55	ns
R x F	12	17.70	2.92	<.0025
L x F	12	38.40	6.34	<.001
M x S x F	4	25.35	4.18	<.0025
M x R x F	12	7.50	1.24	ns
M x L x F	12	27.30	4.50	<.001
S x R x F	12	7.40	1.22	ns
S x L x F	12	5.64	0.93	ns
R x L x F	36	5.11	0.84	ns
M x S x R x F	12	7.59	1.25	ns
M x S x L x F	12	8.05	1.33	ns
M x R x L x F	36	4.38	0.72	ns
S x R x L x F	36	4.89	0.81	ns
M x S x R x L x F	36	4.00	0.66	ns
Error (within)	768	6.06		

*ns = not significant, with p [F | n_1, n_2] > .05

[1] For the purposes of carrying out the analysis on the complete experiment, the 64 Adults (2 L) were randomly assigned to the two schools, half to one, and half to the other.

TABLE 31

Analysis of Variance, Main Recognition Experiment, Based on Each S's Total Number of "New" Errors for 192 Ss of Grades 1, 3, and 5.

Source of Variation	df	Mean Square	F	p
Between Ss				
Modality (M)	1	241.94	7.03	<.01
School (S)	1	287.58	8.36	<.005
Reading Level (R)	2	4775.17	138.84	<.001
List (L)	3	10.313	0.30	ns
M × S	1	73.448	2.14	ns
M × R	2	70.38	2.04	ns
M × L	3	18.673	0.54	ns
S × R	2	57.305	1.67	ns
S × L	3	47.775	1.39	ns
R × L	6	17.380	0.50	ns
M × S × R	2	3.444	0.10	ns
M × S × L	3	12.573	0.365	ns
M × R × L	6	26.777	0.778	ns
S × R × L	6	14.460	0.420	ns
M × S × R × L	6	33.838	0.983	ns
Error (between)	144	34.406		
Within S				
Frequency (F)	2	4488.77	622.91	<.001
M × F	2	66.310	9.202	<.001
S × F	2	0.112	0.015	ns
R × F	4	1.897	0.263	ns
L × F	6	8.396	1.165	ns
M × S × F	2	6.777	0.94	ns
M × R × F	4	7.873	1.093	ns
M × L × F	6	7.511	1.042	ns
S × R × F	4	5.548	0.77	ns
S × L × F	6	1.603	0.22	ns
R × L × F	12	6.311	0.876	ns
M × S × R × F	4	0.770	0.107	ns
M × S × L × F	6	8.028	1.114	ns
M × R × L × F	12	7.416	1.029	ns
S × R × L × F	12	2.328	0.323	ns
M × S × R × L × F	12	5.601	0.777	ns
Error (within)	288	7.206		

TABLE 32

Analysis of Variance, Main Recognition Experiment, Based on each S's Total Number of False Alarm Errors for 192 Ss of Grades 1, 3, and 5.

Source of Variation	df	Mean Square	F	p
Between Ss				
Modality (M)	1	107.36	2.75	<.10
School (S)	1	38.11	0.98	ns
Reading Level (R)	2	961.39	24.94	<.001
List (L)	3	180.77	4.66	<.01
M x S	1	3.36	0.09	ns
M x R	2	93.38	2.43	ns
M x L	3	3.51	0.09	ns
S x R	2	33.19	0.86	ns
S x L	3	11.46	0.30	ns
R x L	6	57.84	1.49	ns
M x S x R	2	26.71	0.69	ns
M x S x L	3	11.67	0.31	ns
M x R x L	6	5.02	0.13	ns
S x R x L	6	44.74	1.16	ns
M x S x R x L	6	13.80	0.36	ns
Error (between)	144	38.58		
Within S				
Frequency (F)	2	2650.08	360.37	<.001
M x F	2	53.46	7.26	<.01
S x F	2	17.38	2.36	ns
R x F	4	25.66	3.49	<.01
L x F	6	30.86	4.19	<.001
M x S x F	2	58.31	7.92	<.0005
M x R x F	4	10.43	1.42	ns
M x L x F	6	31.98	4.34	<.001
S x R x F	4	3.03	0.41	ns
S x L x F	6	5.60	0.76	ns
R x L x F	12	5.30	0.72	ns
M x S x R x F	4	0.30	0.04	ns
M x S x L x F	6	8.24	1.12	ns
M x R x L x F	12	6.40	0.87	ns
S x R x L x F	12	6.20	0.84	ns
M x S x R x L x F	12	4.33	0.59	ns
Error (within)	288	7.36		

TABLE 33

Analysis of Variance, Main Recognition Experiment,
Based on each S's Total Number of "New" Errors,
for 64 Adults.

Source of Variation	df	Mean Square	F	p
Between Ss				
Modality (M)	1	2.76	0.27	ns
School (S)	1	3.26	0.32	ns
List (L)	3	26.83	2.63	ns
M x S	1	0.00	0.00	ns
M x L	3	1.18	0.12	ns
S x L	3	14.53	1.42	ns
M x S x L	3	16.30	1.60	ns
Error (between)	48	10.21		
Within S				
Frequency (F)	2	61.63	18.62	< .001
M x F	2	0.69	0.21	ns
S x F	2	10.82	3.27	< .05
L x F	6	0.87	0.26	ns
M x S x F	2	11.13	3.36	< .05
M x L x F	6	4.89	1.48	ns
S x L x F	6	5.30	1.60	ns
M x S x L x F	6	2.50	0.75	ns
Error (within)	96	3.31		

TABLE 34

Analysis of Variance, Main Recognition Experiment, Based on each S's Total Number of False Alarm Errors, for 64 Adults.

Source of Variation	df	Mean Square	F	p
Between Ss				
Modality (M)	1	59.63	8.35	<.01
School (S)	1	1.50	0.21	ns
List (L)	3	61.17	8.57	<.005
M x S	1	12.50	1.75	ns
M x L	3	1.74	0.24	ns
S x L	3	9.34	1.31	ns
M x S x L	3	0.42	0.06	ns
Error (between)	48	7.14		
Within S				
Frequency (F)	2	119.14	41.40	<.001
M x F	2	8.08	2.81	ns
S x F	2	8.33	2.90	ns
L x F	6	25.50	8.86	<.001
M x S x F	2	6.90	2.40	ns
M x L x F	6	2.01	0.70	ns
S x L x F	6	1.69	0.59	ns
M x S x L x F	6	2.62	0.91	ns
Error (within)	96	2.88		

TABLE 35A

Main Recognition Experiment - Total "New" Errors - All S's

Modality by Frequency

Modality

Frequency	Auditory (N = 128)	Visual (N = 128)	Difference (V-A)
High	488	675	+ 187
Low	716	880	+ 164
Non-Words	913	958	+ 45
Σ	2117	2513	

TABLE 35B

Total False Alarm Errors - All S's

Modality

Frequency	Audition (N = 128)	Vision (N = 128)	Difference (V-A)
High	647	770	+ 127
Low	1198	951	- 247
Non-Words	810	763	- 47
Σ	2655	2484	

TABLE 36A

Main Recognition Experiment - Total "New" Errors - All S's

Frequency by Reading Level

		Frequency					
Reading Level	N	High	Diff. H-L	Low	Diff. L-N	Non-Words	Diff. H-N
1st	64	436	-134	570	- 51	621	-185
3rd	64	335	-128	463	- 62	525	-190
5th	64	213	-162	375	- 58	433	-220
Adults	64	179	- 9	188	-104	292	-113
Σ	256	1163		1596		1871	

TABLE 36B

Total False Alarm Errors - All S's

		Frequency					
Reading Level	N	High	Diff. H-L	Low	Diff. L-N	Non-Words	Diff. H-N
1st	64	628	- 49	677	+ 53	624	+ 4
3rd	64	373	-163	536	+158	378	- 5
5th	64	357	-176	533	+163	370	-13
Adults	64	257	-166	423	+156	267	-10
Σ	256	1615		2169		1639	

TABLE 37A

Main Recognition Experiment - Total "New" Errors

Modality by Reading Level

Reading Level	N	Modality Audition (N = 128)	N	Vision (N = 128)	Diff. (V-A)	Total
1	32	685	32	942	+257	1627
3	32	627	32	696	+ 69	1323
5	32	487	32	534	+ 47	1021
Adult	32	318	32	341	+ 23	659
Σ	128		128			

TABLE 37B

Total False Alarm Errors

Modality by Reading Level

Reading Level	N	Modality Audition (N = 128)	N	Vision (N = 128)	Diff. (V-A)	Total
1	32	933	32	990	+ 57	1923
3	32	777	32	570	-207	1347
5	32	728	32	634	- 94	1362
Adult	32	417	32	310	-107	727
Σ	128		128			

TABLE 38A

Main Recognition Experiment - Total "New" Errors

Frequency by Reading Level for Auditory Presentation

Reading Level	N	Frequency				
		High	Diff. H-L	Low	Diff. L-N	Non-Words
1st	32	162	-69	231	-61	292
3rd	32	154	-68	222	-29	251
5th	32	90	-82	172	-53	225
Adult	32	82	- 9	91	-54	145
Σ	128					

TABLE 38B

Total False Alarm Errors

Reading Level	N	Frequency				
		High	Diff. H-L	Low	Diff. L-N	Non-Words
1st	32	292	- 67	359	+ 77	282
3rd	32	235	- 90	325	+108	217
5th	32	193	-119	312	+ 89	223
Adult	32	107	- 95	202	+ 94	108
Σ	128					

TABLE 33A

Main Recognition Experiment - Total "Yes" Errors

Frequency by Reading Level for Visual Presentation

		Frequency				
Reading Level	N	High	Diff. H-L	Low	Diff. L-N	Non-Words
1st	32	274	-65	339	+10	329
3rd	32	181	-60	241	-33	274
5th	32	123	-80	203	- 5	208
Adult	32	97	0	97	-50	147
N	128					

TABLE 33B

Total False Alarm Errors

		Frequency				
Reading Level	N	High	Diff. H-L	Low	Diff. L-N	Non-Words
1st	32	336	+18	318	-18	336
3rd	32	158	-73	231	+50	181
5th	32	186	-75	261	+74	187
Adult	32	90	-51	141	+62	79
N	128					

TABLE 10

Probabilities of Correct Recognitions and "New" Errors for the Main Auditory Experiment

Subj. No.	1st Grade p("New"/New)*	1st Grade p("New"/Old)	Subj. No.	3rd Grade p("New"/New)*	3rd Grade p("New"/Old)	Subj. No.	5th Grade p("New"/New)*	5th Grade p("New"/Old)	Subj. No.	Adults p("New"/New)*	Adults p("New"/Old)
1	.889	.300	17	.800	.344	33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	.789	.133	18	.944	.244	34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	.911	.367	19	.711	.100	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	.522	.211	20	.811	.156	36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	.478	.444	21	.611	.178	37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	.556	.222	22	.767	.144	38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	.878	.267	23	.767	.189	39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	.678	.089	24	.433	.178	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	.556	.267	25	.600	.189	41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	.833	.333	26	.811	.189	42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	.844	.222	27	.700	.133	43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	.978	.233	28	.644	.344	44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	.989	.278	29	.767	.344	45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	.778	.244	30	.822	.467	46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	.800	.189	31	.711	.178	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	.744	.222	32	.756	.122	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
49	.700	.144	65	.656	.178	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	.700	.167	66	.711	.189	82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51	.544	.178	67	.822	.156	83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52	.878	.311	68	.789	.189	84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53	.267	.222	69	.744	.100	85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54	.467	.244	70	.822	.289	86	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55	.711	.156	71	.689	.189	87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
56	.667	.267	72	.722	.233	88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
57	.800	.167	73	.789	.367	89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
58	.778	.189	74	.644	.211	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
59	.600	.133	75	.667	.100	91	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	.533	.222	76	.778	.067	92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
61	.733	.156	77	.711	.367	93	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62	.756	.278	78	.811	.222	94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63	.644	.344	79	.756	.100	95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
64	.433	.078	80	.800	.111	96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	.676	.238		.730	.218		.767	.189		[illegible]	[illegible]

d' =1.18 d' =1.36 d' =1.62 d' =2.33

*These equal one minus the false alarm rate, [1-p("old"/new)].

TABLE 41

Probabilities of Correct Recognitions and "New" Errors for the Main Visual Experiment

Subj. No.	1st Grade p("New"/New)*	1st Grade p("New"/Old)	Subj. No.	3rd Grade p("New"/New)*	3rd Grade p("New"/Old)	Subj. No.	5th Grade p("New"/New)*	5th Grade p("New"/Old)	Subj. No.	Adults p("New"/New)*	Adults p("New"/Old)
97	.978	.567	113	.933	.389	129	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
98	.811	.367	114	.889	.289	130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
99	.989	.133	115	.911	.189	131	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100	.744	.411	116	.744	.222	132	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
101	.767	.489	117	.789	.344	133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
102	.633	.444	118	.867	.222	134	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
103	.444	.367	119	.789	.467	135	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
104	.611	.356	120	.756	.178	136	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
105	.356	.144	121	.956	.300	137	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
106	.667	.311	122	.867	.278	138	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
107	.700	.400	123	.778	.089	139	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
108	.633	.311	124	.856	.422	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
109	.633	.478	125	.867	.289	141	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
110	.767	.367	126	.756	.233	142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
111	.589	.433	127	.822	.311	143	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
112	.689	.411	128	.789	.467	144	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
145	.700	.189	161	.867	.256	177	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
146	.833	.256	162	.944	.300	178	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
147	.500	.322	163	.844	.211	179	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
148	.767	.278	164	.767	.111	180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
149	.367	.122	165	.756	.178	181	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	.478	.433	166	.944	.078	182	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
151	.644	.156	167	.944	.344	183	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
152	.644	.200	168	.867	.156	184	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
153	.567	.222	169	.956	.300	185	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
154	.767	.400	170	.811	.400	186	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
155	.533	.178	171	.956	.078	187	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
156	.856	.422	172	.911	.322	188	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
157	.589	.478	173	.778	.344	189	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
158	.889	.178	174	.822	.133	190	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
159	.544	.111	175	.733	.022	191	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
160	.711	.433	176	.844	.111	192	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	.656	.327		.842	.242		[illegible]	[illegible]		[illegible]	[illegible]
	d'=.85			d'=1.56			d'=1.49			d'=1.80	

*These equal one minus the false alarm errors, [1-p("old"/new)].

TABLE 42

Proportions of Individuals (N = 32) Having a Performance Level Superior to the Mean Performance Level of the Reference Group on [illegible] Plate.

Experimental Group		Superior to mean performance level of Grade 1			
	Grade	1	3	5	Adult
Auditory		.41	.59	.81	1.00
Visual		.34	.75	.97	1.00

	Superior to mean performance level of *own Grade*			
	1	3	5	Adult
Auditory	.41	.38	.38	.25
Visual	.34	.31	.38	.38

APPENDIX III: Figures

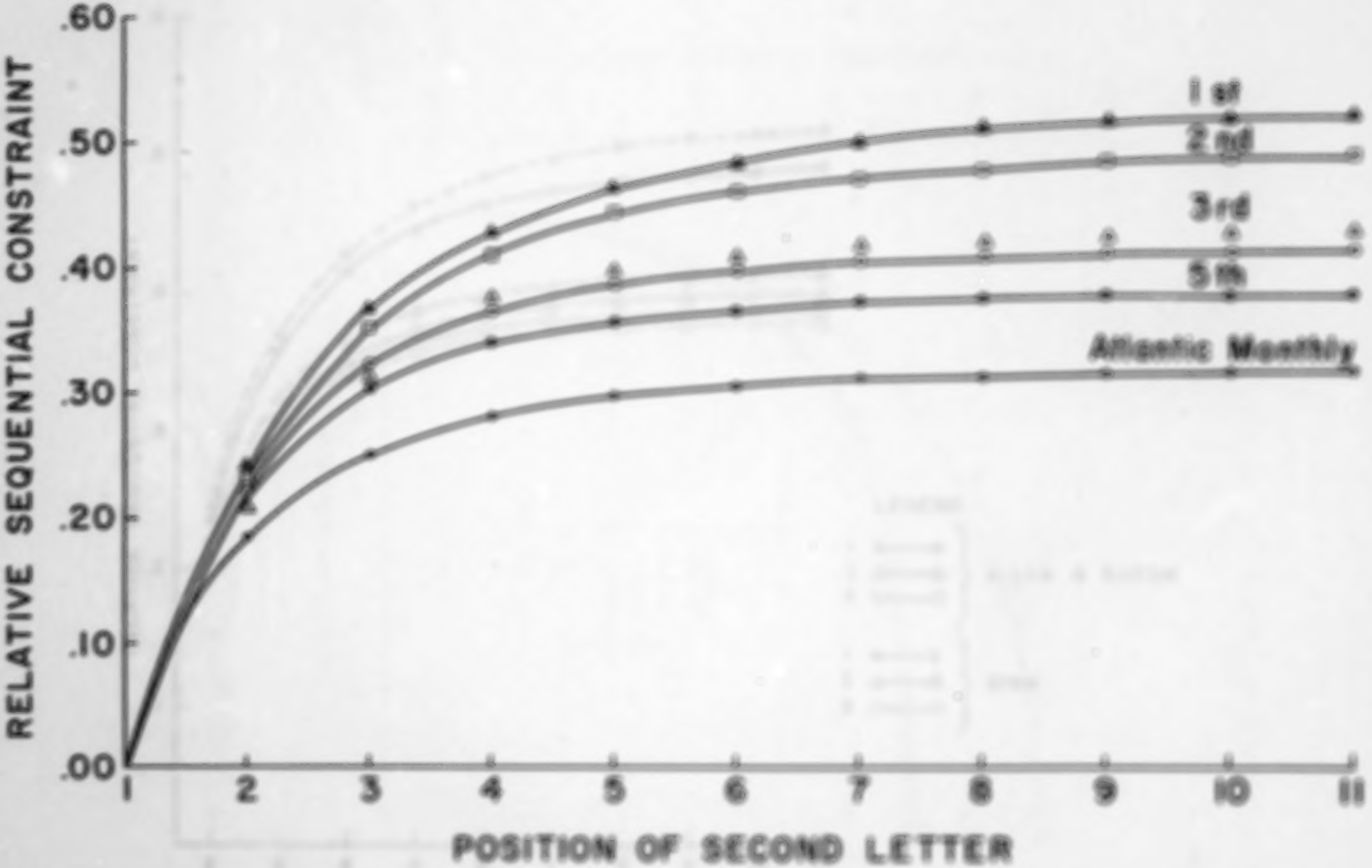
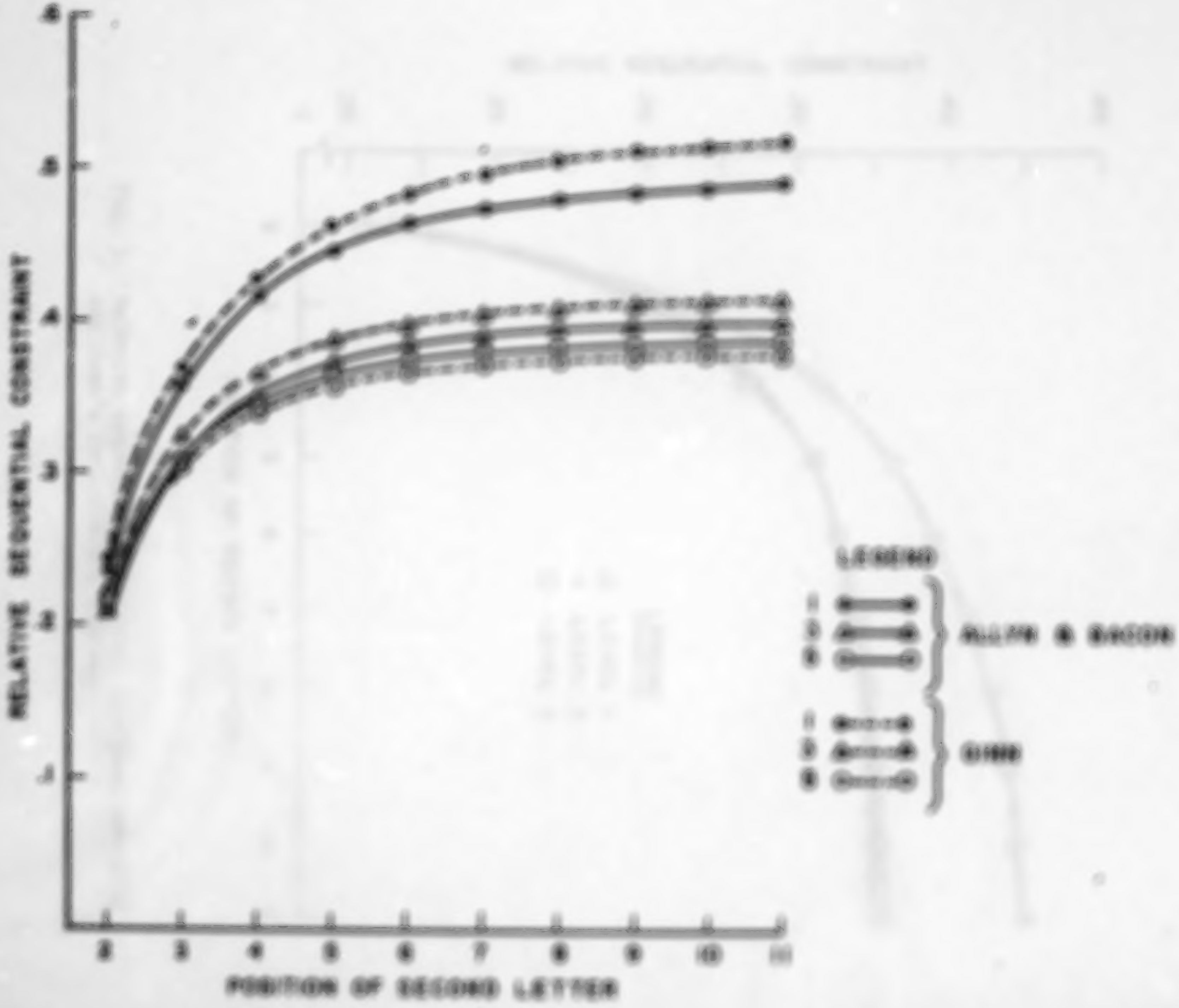


Fig. 1. Relative sequential constraint, C_{1i}, of the letter in the i^{th} position. Four graded readers are shown. The Atlantic Monthly gives a lower bound for relatively complex texts. The English Bible is shown by open triangles.


.6
.5
.4
.3
.2
.1
RELATIVE SEQUENTIAL CONSTRAINT
2
3
4
5
6
7
8
9
10
11
POSITION OF SECOND LETTER
LEGEND
1
2
3
ALLYN & BACON
1
2
3
GINN

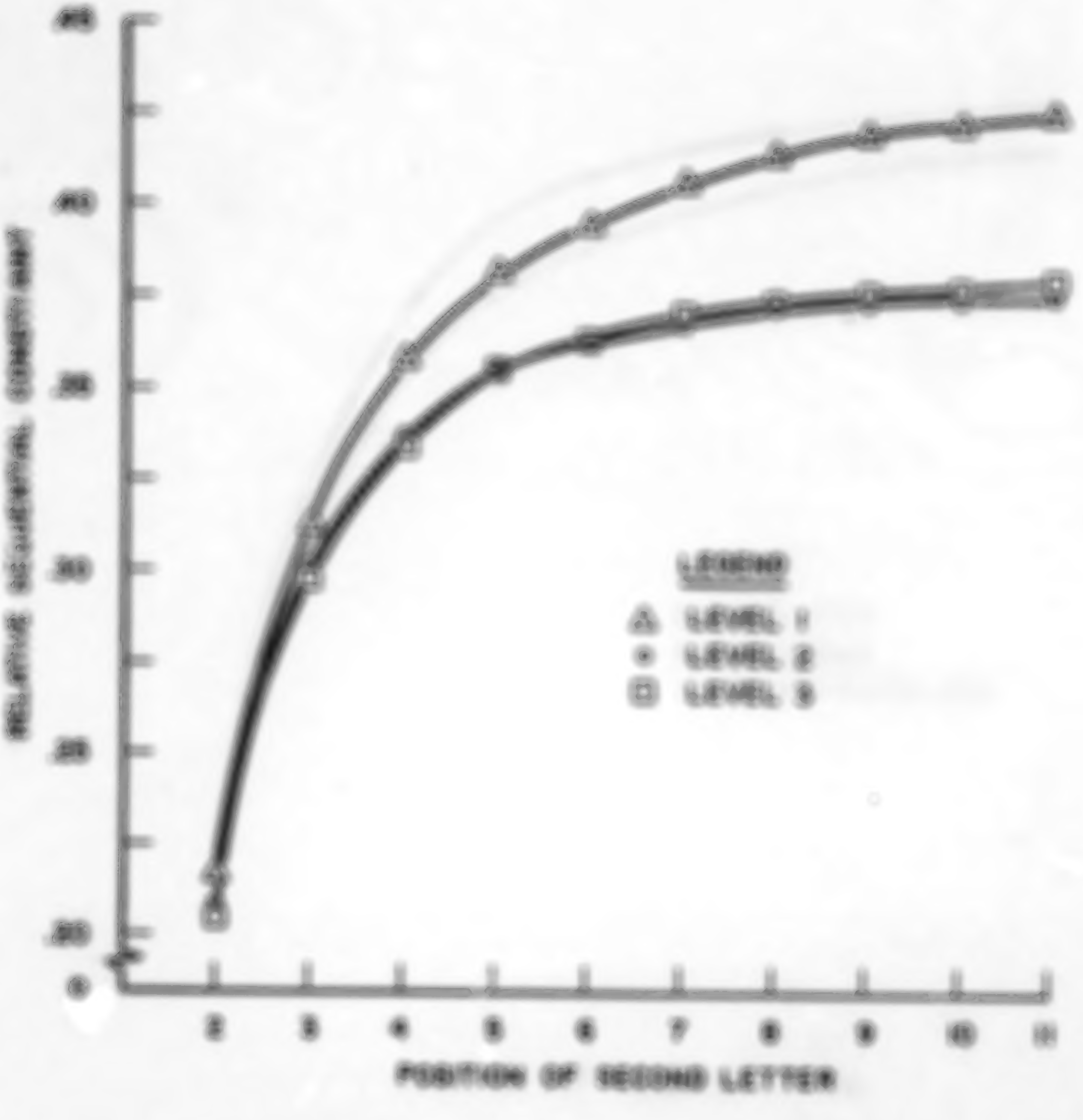


Fig. 3. Relative sequential constraint in three levels of children's free-reading choices.

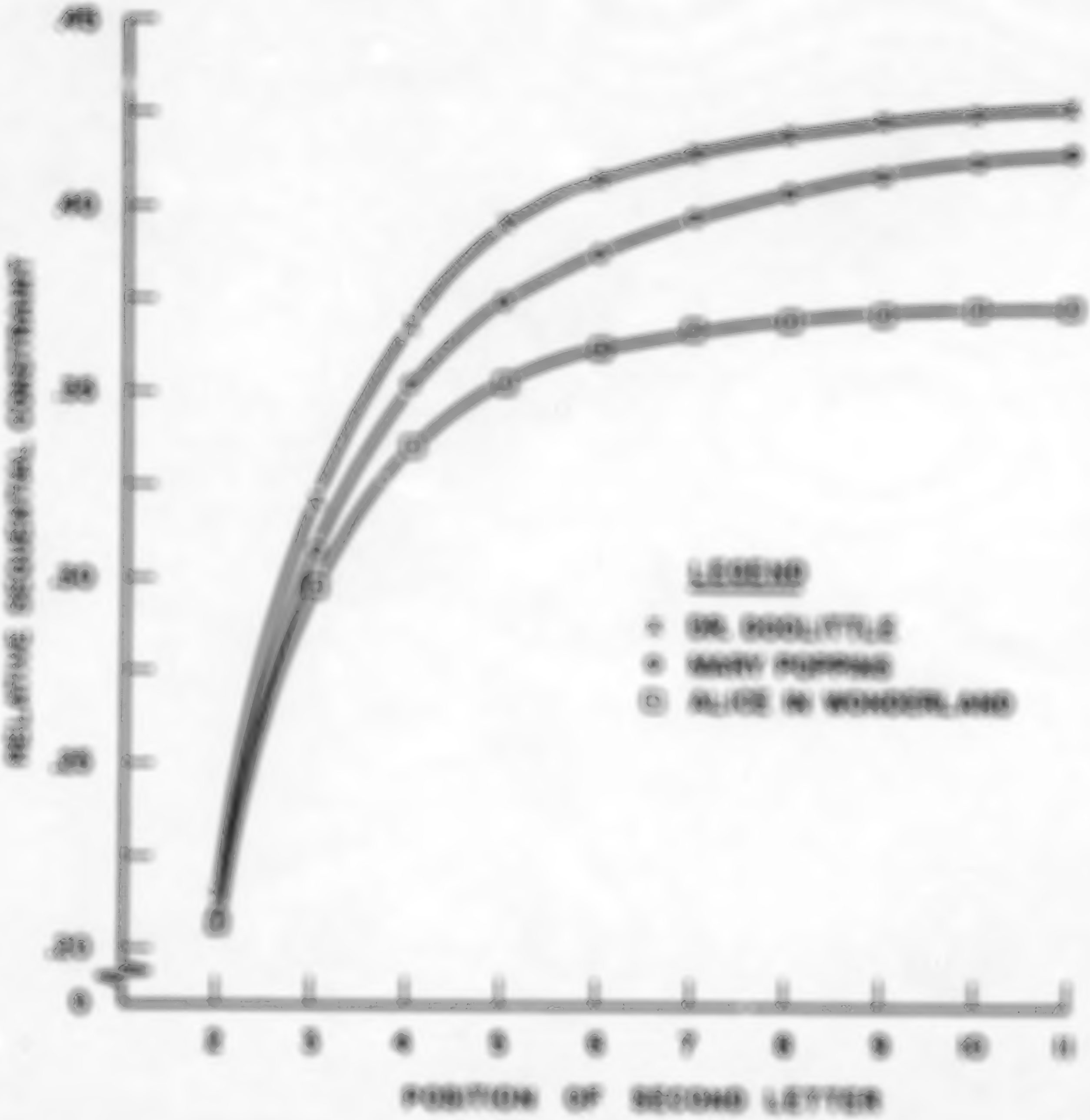


Fig. 4. Relative sequential constraint in three texts of children's free-reading choices at level 3.

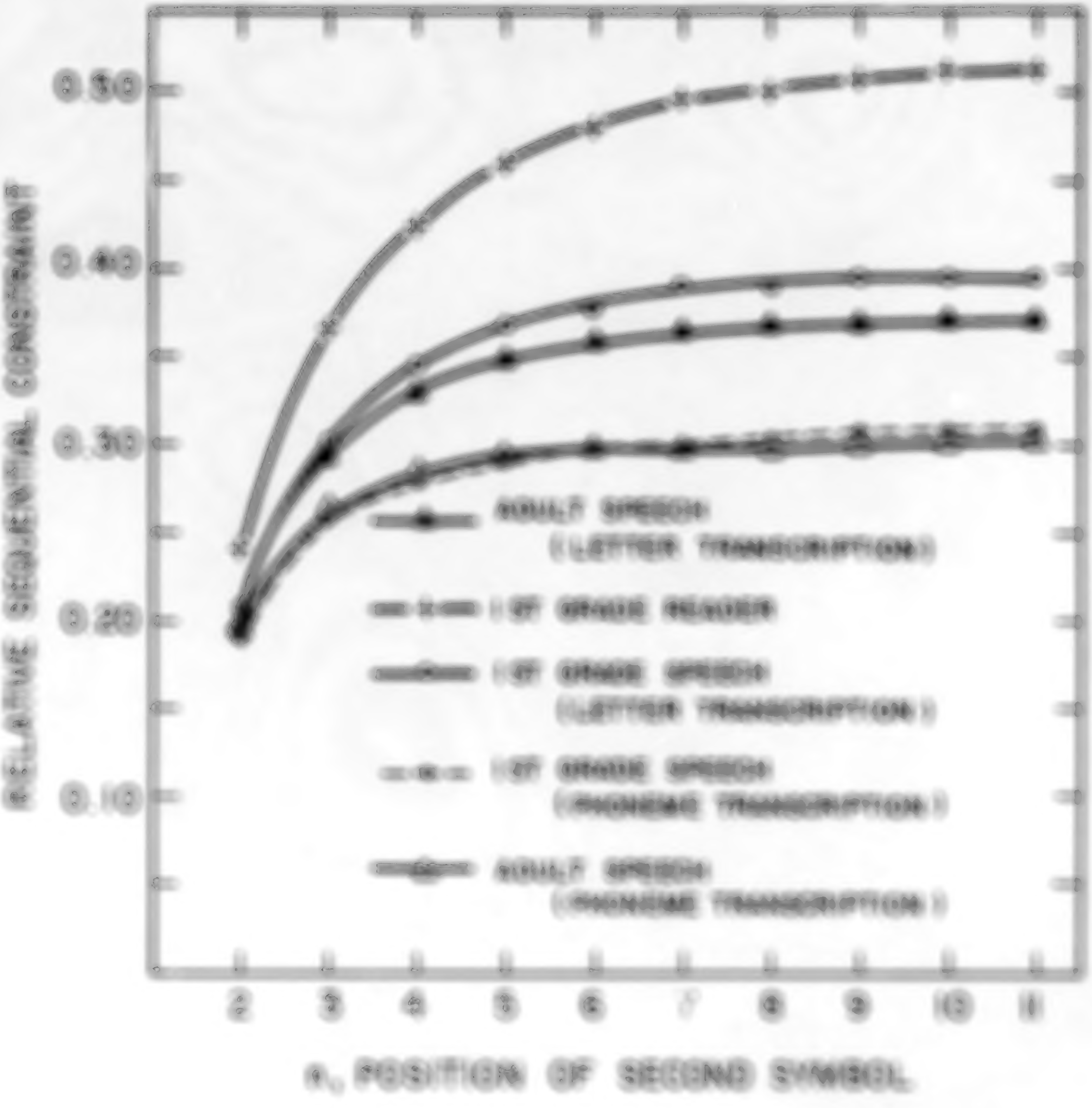


Fig. 5. Relative sequential constraint in letter or phoneme transcriptions of the speech of first graders and adults and in a First Reader.

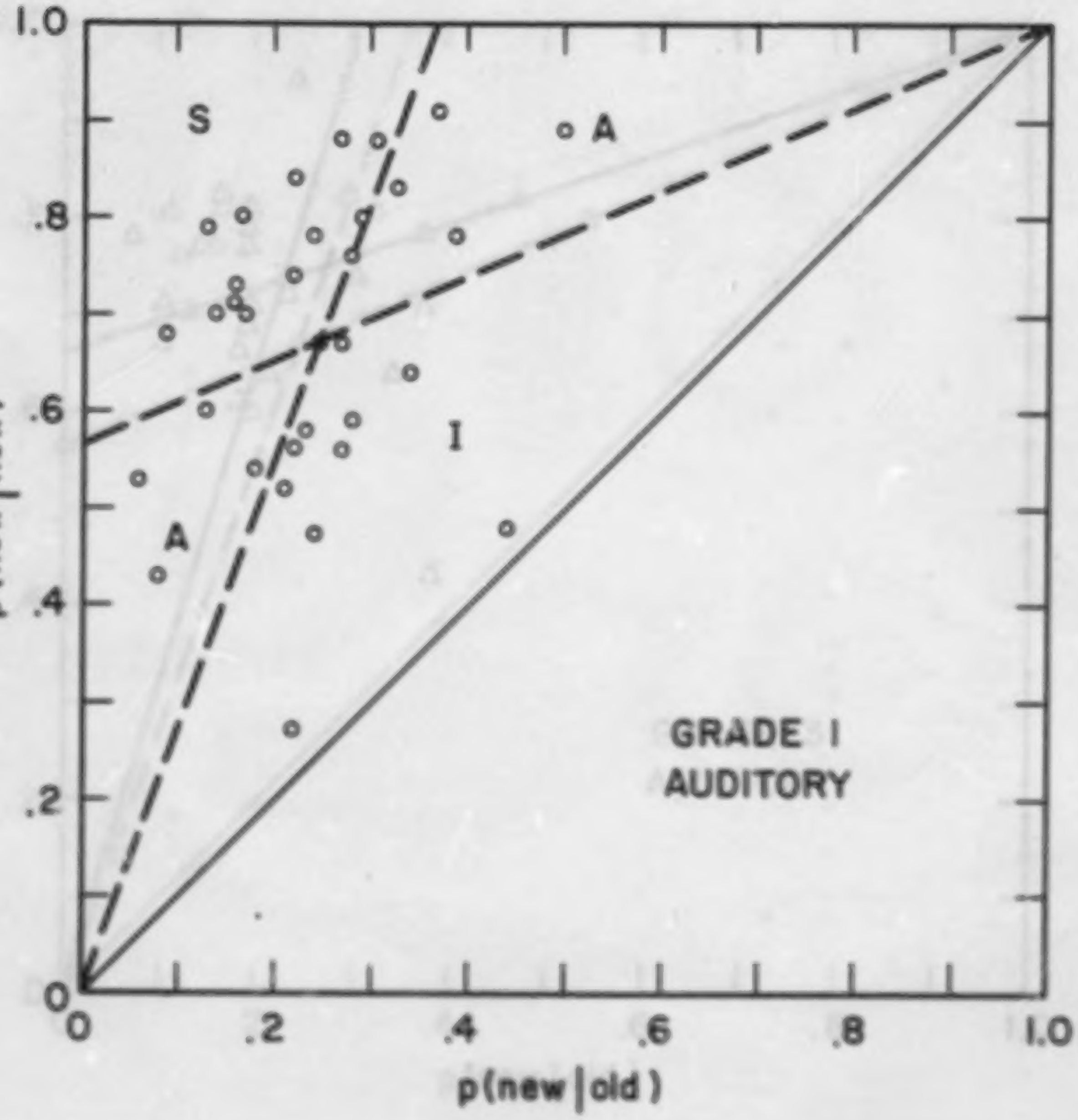


Fig. 6. ROC plots for the auditory recognition task for First Graders.

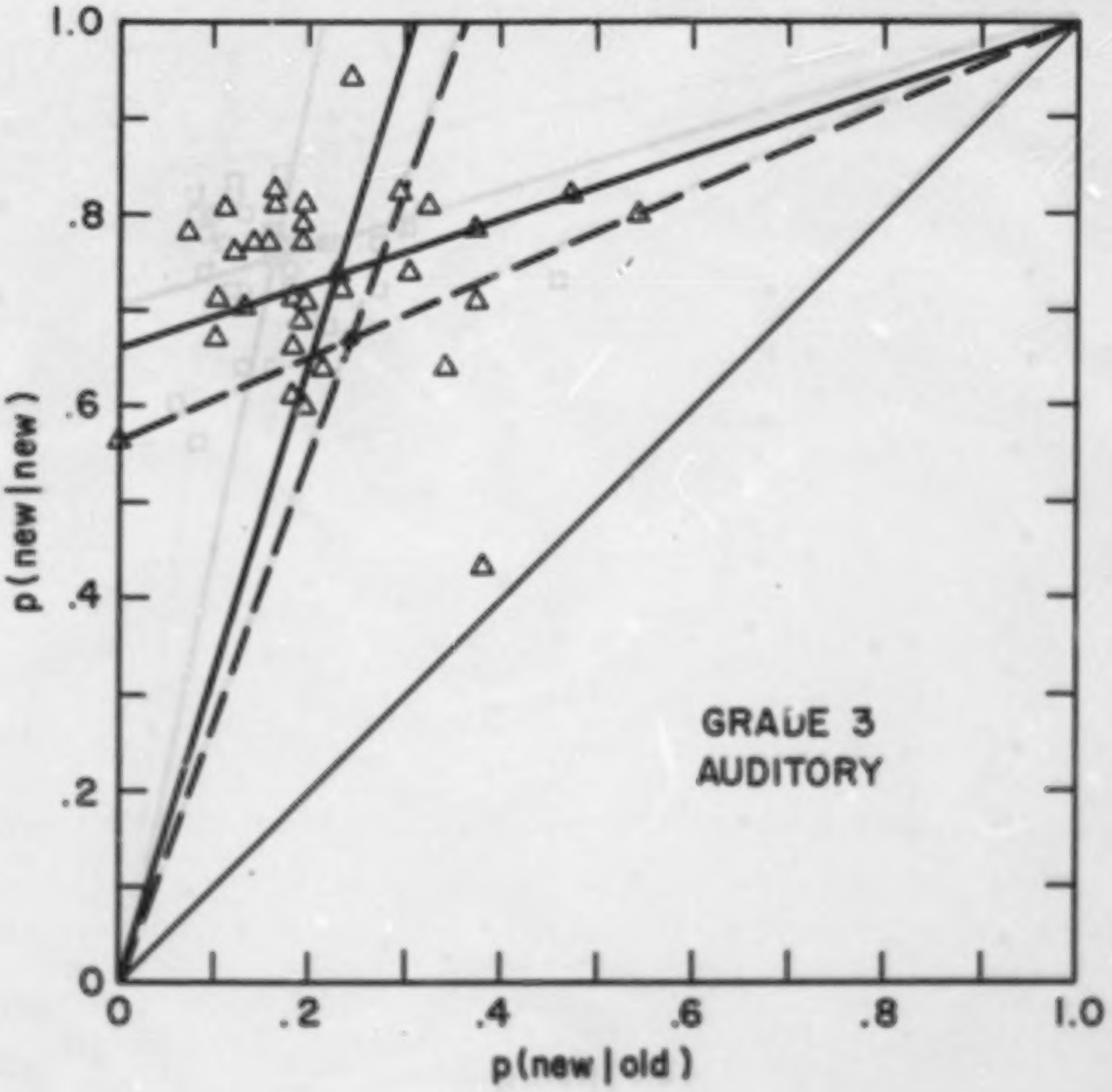


Fig. 7. ROC plots for the auditory recognition task for Third Graders.

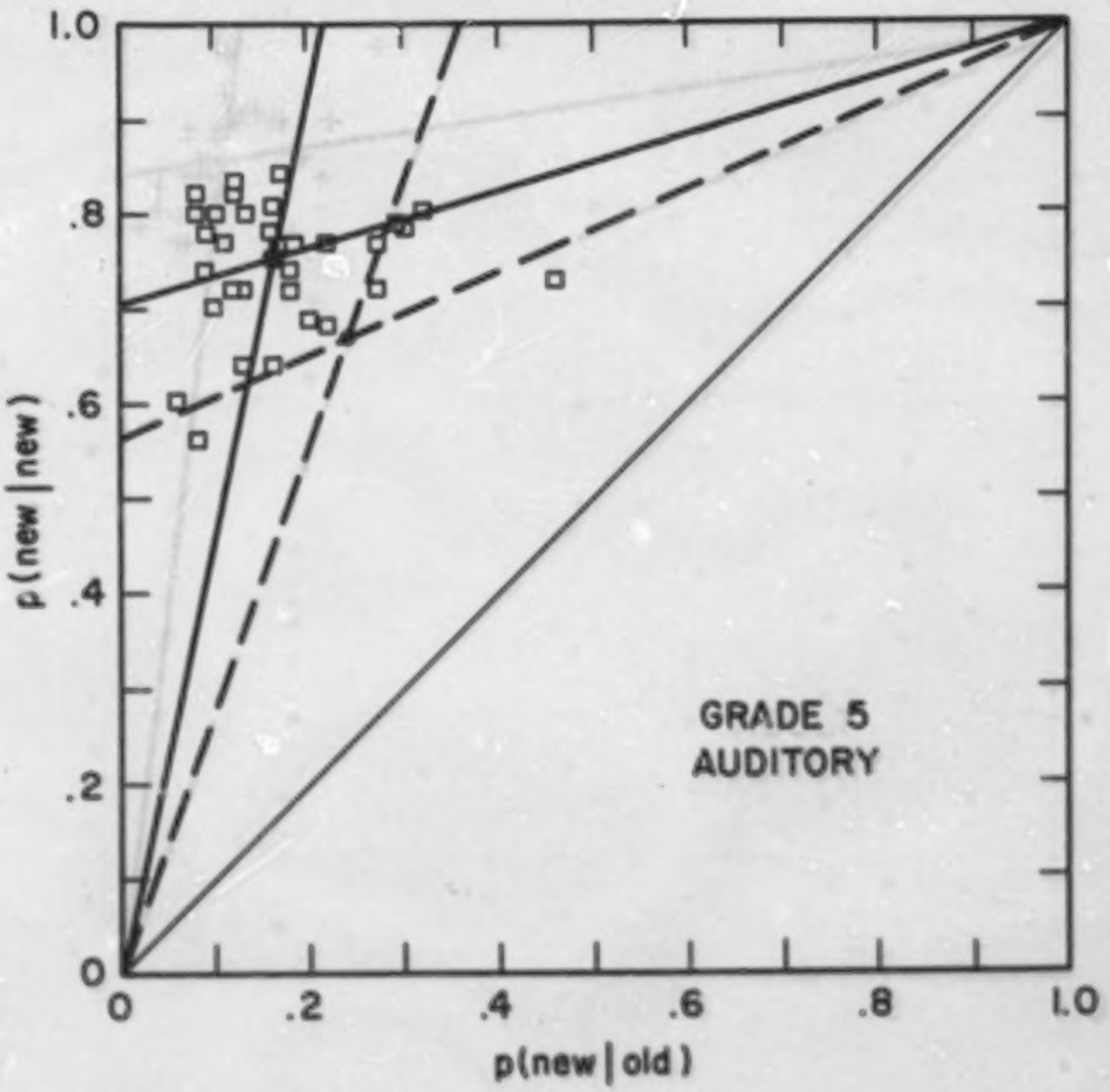


Fig. 8. ROC plots for the auditory recognition tasks for Fifth Graders.

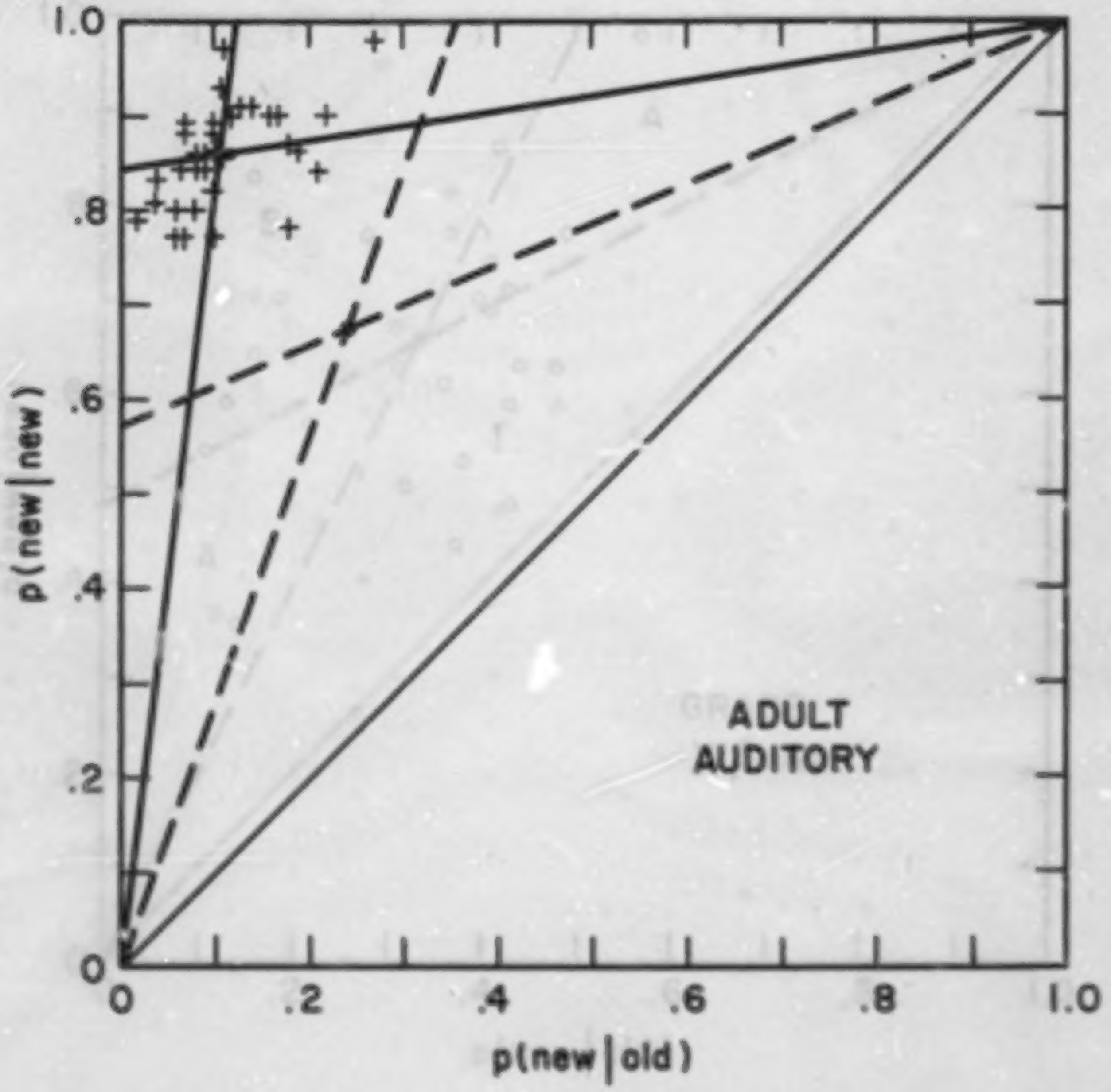


Fig. 9. ROC plots for the auditory recognition task for Adults.

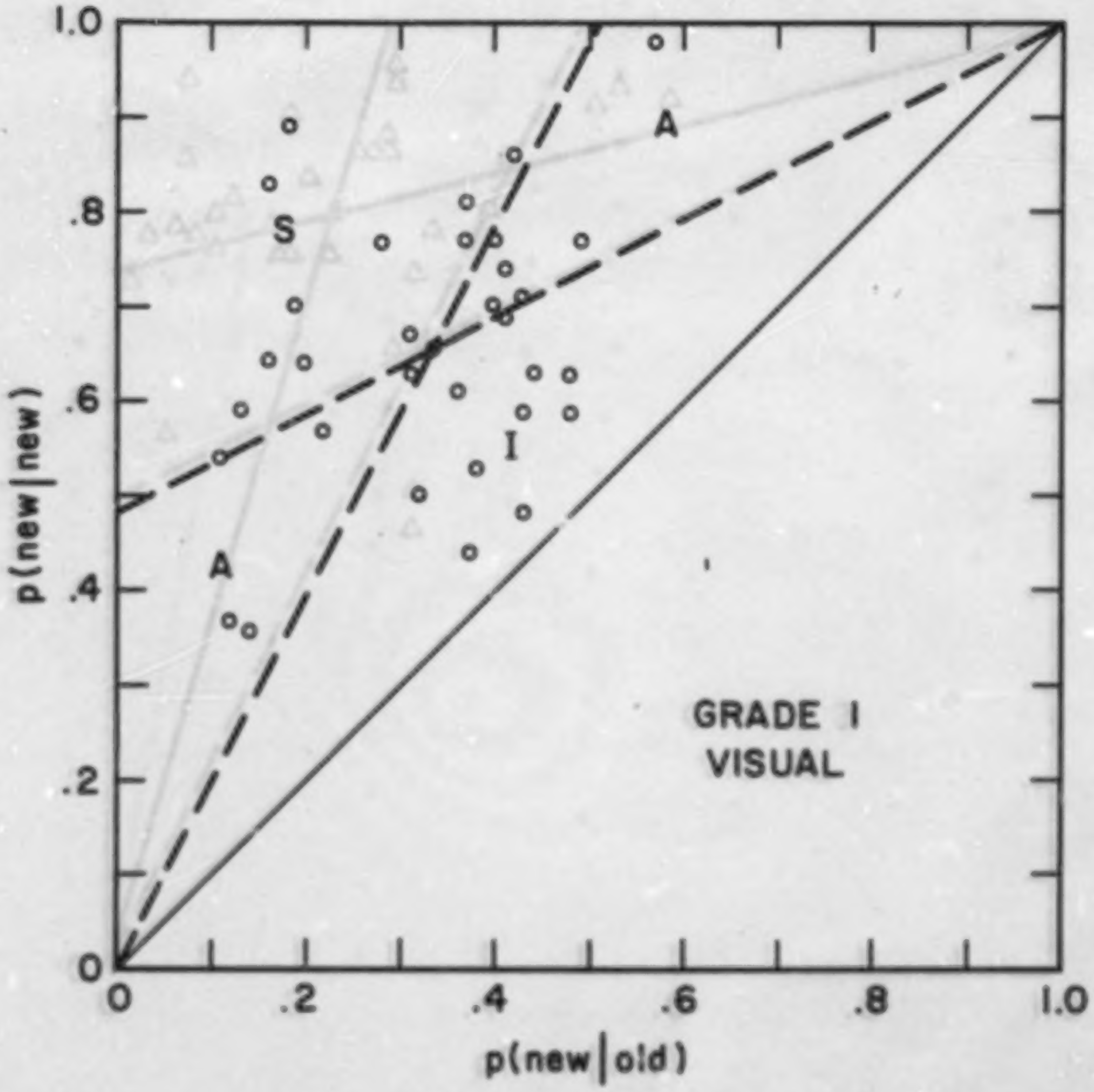


Fig. 10. ROC plots for the visual recognition task for First Graders.

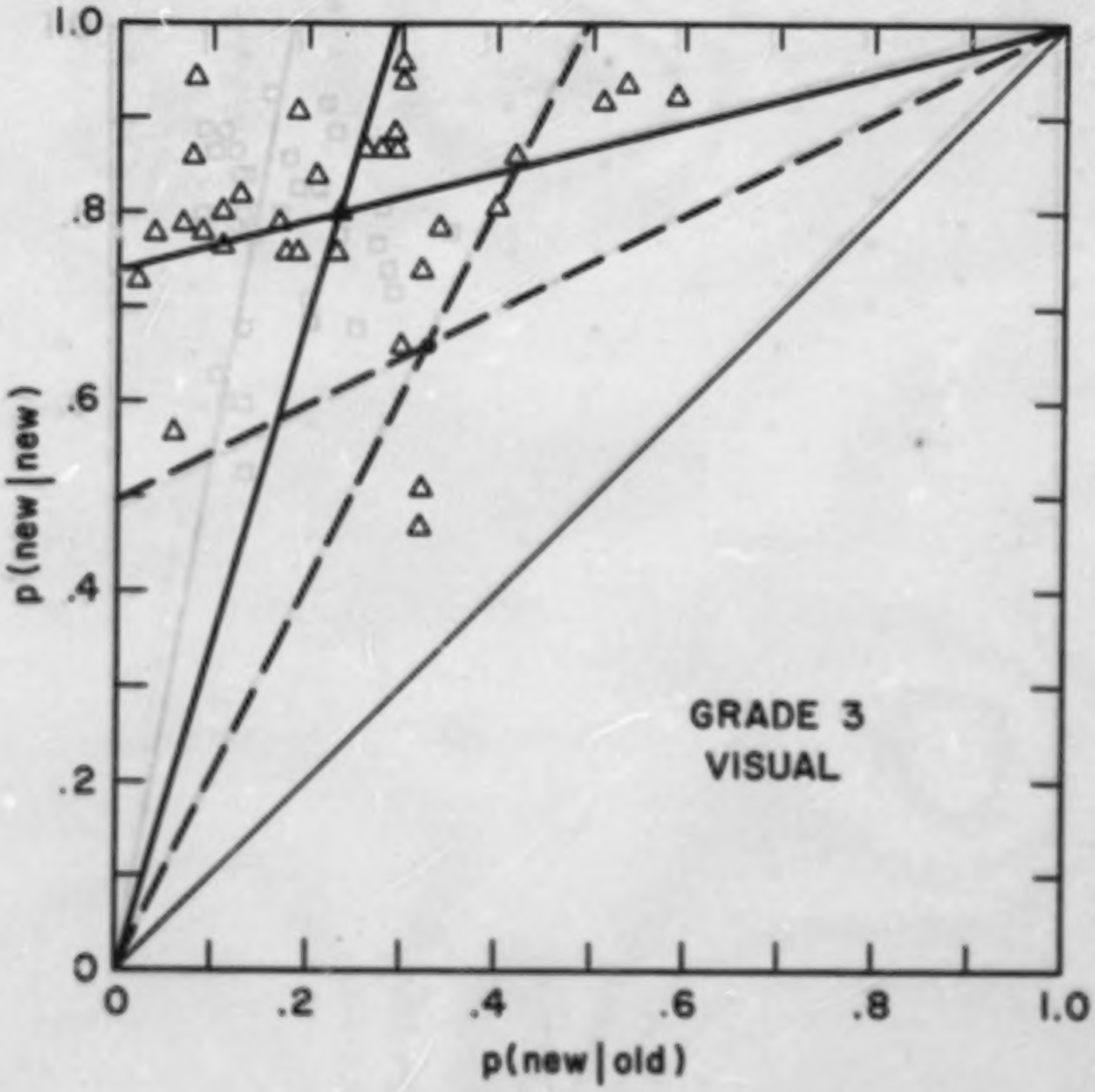


Fig. 11. ROC plots for the visual recognition task for Third Graders.

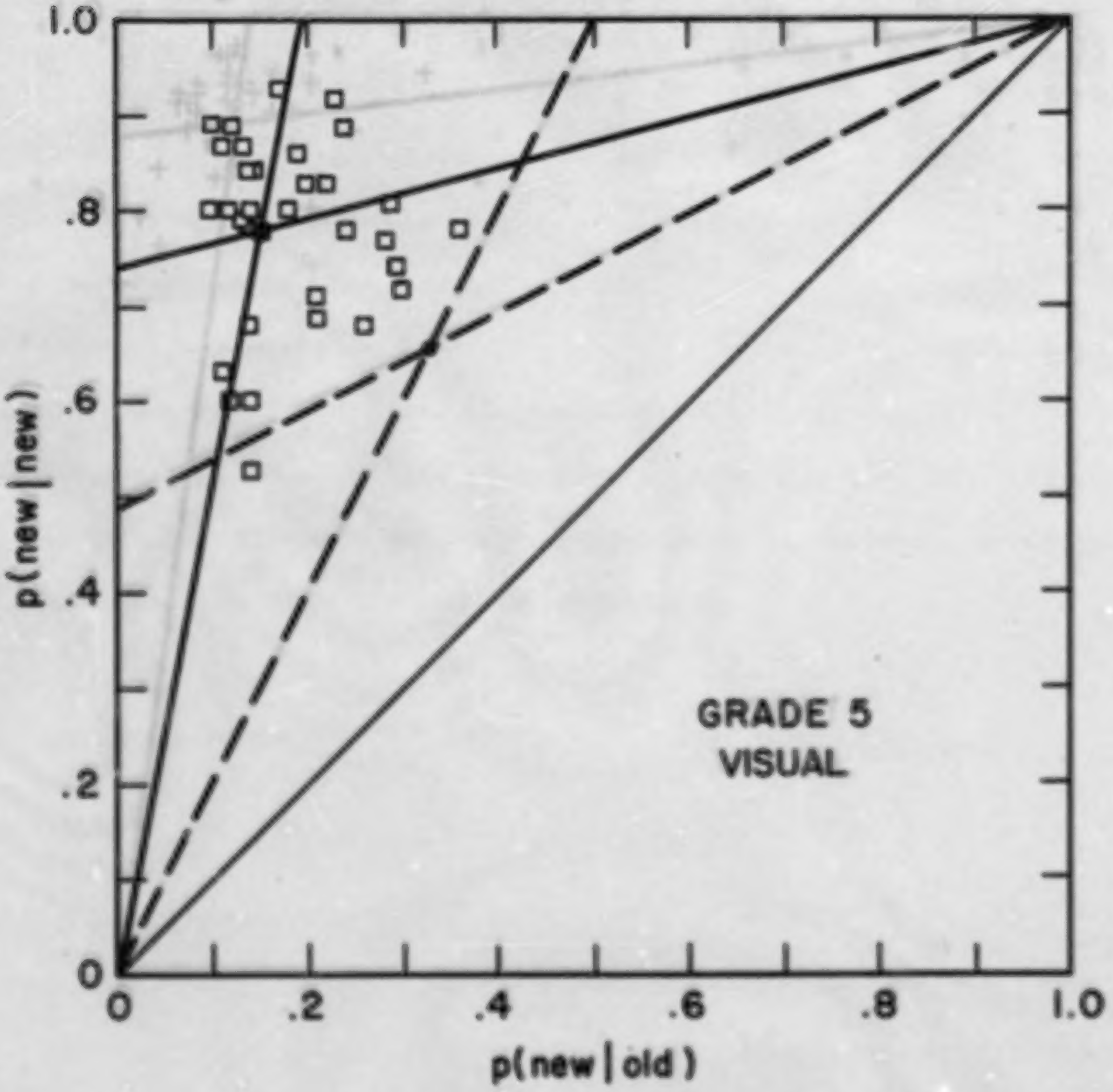


Fig. 12. ROC plots for the visual recognition task for Fifth Graders.

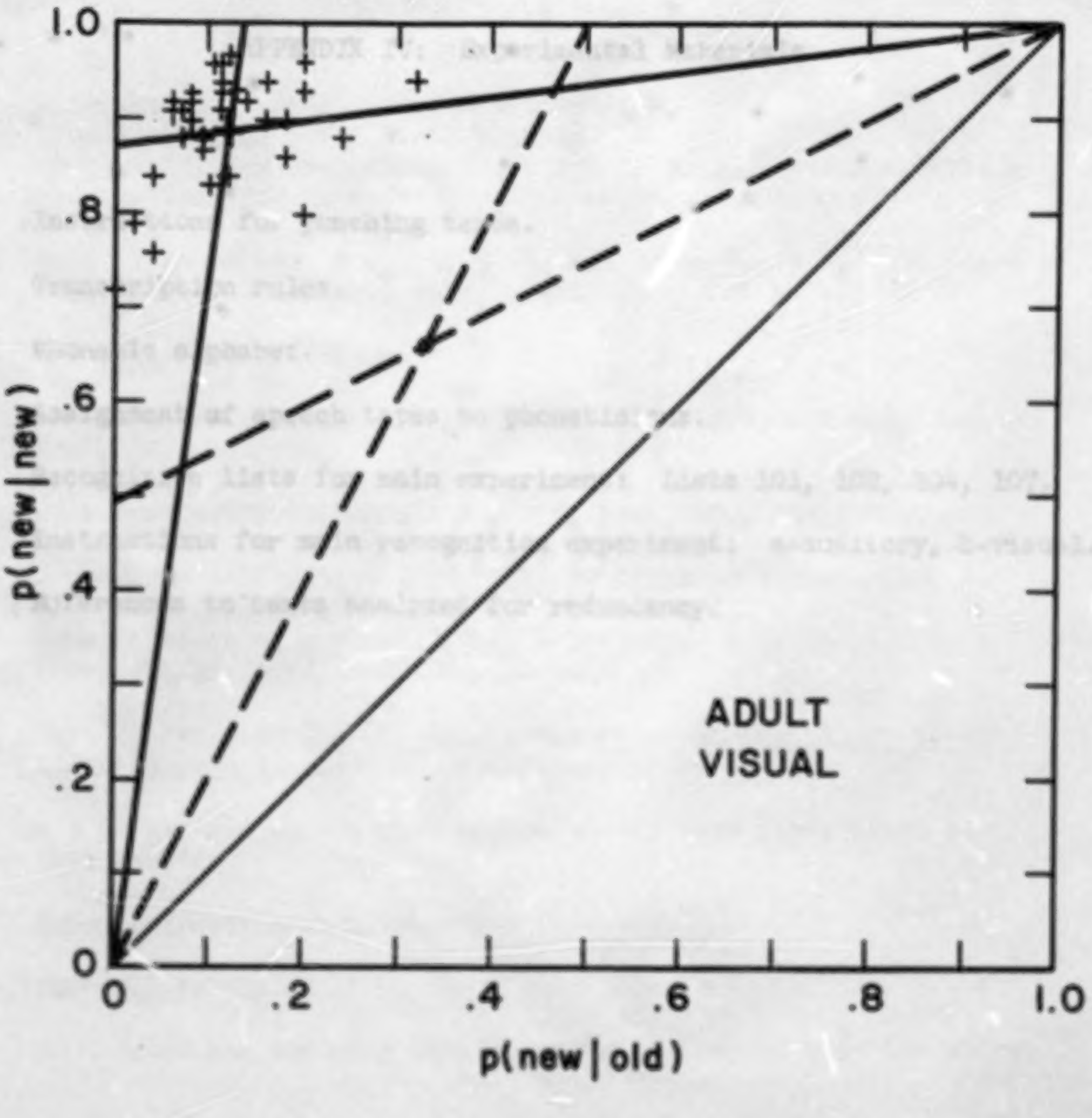


Fig. 13. ROC plots for the visual recognition task for Adults.

APPENDIX IV: Experimental Materials

1. Instructions for punching texts.
2. Transcription rules.
3. Phonemic alphabet.
4. Assignment of speech tapes to phoneticians.
5. Recognition lists for main experiment: Lists 101, 102, 104, 107.
6. Instructions for main recognition experiment: a-auditory, b-visual.
7. References to texts analyzed for redundancy.

1. INSTRUCTIONS FOR PUNCHING TEXTS

1. Disregard all punctuation except periods.
   [Ignore dashes; put a slash instead.]
   Use periods for semicolons (if properly used), question marks, and exclamation points.
2. Omit all numerals, i.e., 1, 5, 8, but leave those in that are written out, i.e., one, five, eight.
3. Omit all foreign phrases.
4. Write contractions as they are, omitting the apostrophe, i.e., DONT, IM, etc.
5. Omit mere abbreviations, i.e., Mr., Mrs., St., Ave., etc.
6. Use column 1-72 only. (Rest are for sequence numbering.)
7. Punch a space as a slash; punch a period as a period, i.e., ONE/DAY/LONG/LONG/AGO./THE/DOG/
8. Omit titles like The Old Sled (Page 41). In Our Cherry Street start on page 41 and punch continuously through page 218.
9. A * to be used as the last symbol on the last card, after the last period.
10. Error correction--a minus sign.
11. Omit all poetry.
12. If a story has too many foreign words and names, omit the story.

2. TRANSCRIPTION RULES

1. If you can't understand a word or any part of a sentence, skip the whole sentence.

2. Transcribe the sounds, not what the word should be, or was last time. Don't normalize the data.

3. Put in 'noise words': "We-e-e-ll", "uhm-m".

4. Don't put in non-phonemic symbols.

5. Watch these pairs that are often neutralized: ɔ and ɑ.

6. Biggest problem: stressed or unstressed -- ə or stressed vowel. Listen carefully for this. If you can hear the quality, then use the stressed vowel. If in doubt, use schwa.

7. Sentence boundary: Terminal break; rising or falling intonation. Symbol - period.

8. Word boundary: slight phonetic pause between phoneme sequences with no particular intonation pattern. These should be marked as they sound, not as written words would demand. No grammatical definition.

9. Do not put in sheer stammers. (These are infrequent.)

10. Do put in word or phrase repetitions.

11. Start transcription only after they are warmed up. Arrow indicates start.

12. Leave out repetition of words when in answer to question like "what?"

13. If sentences are spoken at once by several people and are not clear - leave out.

14. Interrupted but continued sentences should be included if unequivocal. Leave out the interruption.

15. Leave out all speech of an individual with even minor speech pathologies and all with indications of foreign language influence. (This should include British English, Boston English, Southern accents, Brooklynese, etc.)

3. PHONEMIC ALPHABET AND FORTRAN ALPHABET CODE

Phonemic Alphabet	Fortran Code	Phonemic Alphabet	Fortran Code
a	A	ɔ	0
b	B	ɨ	)
č	C	θ	2
d	D	ž	3
e	E	ə	4
f	F	ɪw	5
g	G	aw	6
h	H	ay	7
i	I	ey	8
ǰ	J	iy	9
k	K	uw	=
l	L	ʔ	*
m	M	ɔy	$
n	N		
ow	O	Terminal Juncture	.
p	P		
ŋ	Q	Word Mark	/
r	R		
s	S		
t	T		
u	U		
v	V		
w	W		
š	X		
y	Y		
z	Z		

4. ASSIGNMENT OF TAPES TO PHONETICIANS

1. Elite Ohlshtain
   - Grade 1 - 11, 14, 16
   - Grade 3 - 1, 4
   - Grade 5 - 8, 13, 20
   - Adult - 37, 38, 40
2. Robert Chamberlin
   - Grade 1 - 2, 6, 22
   - Grade 3 - 7, 10
   - Grade 5 - 9, 12
   - Adult - 39
3. Jane Chamberlin
   - Grade 1 - 26
   - Grade 3 - 24
   - Grade 5 - 27
4. Herman Pevner
   - Grade 1 - 23, 36
   - Grade 3 - 21, 29, 32
   - Grade 5 - 25, 28

5. RECOGNITION LISTS - MAIN EXPERIMENT

RECOGNITION TASK LIST NO. 181

Auditory ☐
Visual ☐

School__________________ Grade___ Reading Level___

S No.___ Name__________________ Date__________

		032	MAF	064	CAT	096	LOP	128	FIN	160	CAB
001	HAS	033	DID	065	MAF	097	JUT	129	MEX	161	BLD
002	JIB	034	POS	066	KEN	098	VON	130	LOT	162	RED
003	AND	035	TRY	067	CAT	099	VEN	131	VON	163	PRY
004	GOB	036	SUT	068	LAF	100	ONE	132	PLY	164	JAG
005	BIG	037	CUN	069	KEN	101	NUB	133	TOP	165	FLY
006	HAS	038	OLD	070	URE	102	SIN	134	MEX	166	BED
007	FEN	039	ORB	071	TAF	103	APT	135	HOP	167	RED
008	ADO	040	FEN	072	URG	104	FIP	136	TOP	168	FLY
009	FAR	041	ERG	073	SOT	105	URG	137	PIP	169	ASU
010	PET	042	CON	074	PUB	106	FAD	138	RAN	170	YES
011	JIB	043	PET	075	LET	107	BOP	139	HOG	171	FLY
012	FAR	044	ORB	076	SOT	108	VEN	140	HAS	172	ASU
013	ADO	045	SUT	077	HEX	109	FAD	141	MEF	173	PRO
014	BIG	046	CAN	078	DOG	110	TEN	142	FOR	174	VOT
015	FAF	047	OLD	079	LOP	111	FIN	143	WAB	175	TEB
016	DID	048	LOB	080	HEX	112	APT	144	HOD	176	RUB
017	OPA	049	FIN	081	CUN	113	FOD	145	HAG	177	RUT
018	FAF	050	ERG	082	FIN	114	JUT	146	MEF	178	PRO
019	FAS	051	LOB	083	DOG	115	LUG	147	RAB	179	VOT
020	AND	052	FAS	084	CUN	116	FOD	148	HOG	180	RUT
021	GOB	053	YEN	085	JAB	117	TAD	149	WAS	181	ALP
022	RAF	054	CUN	086	YEN	118	NUB	150	TAD	182	TUD
023	SAT	055	RAN	087	URE	119	PUT	151	FOR	183	TUB
024	DAT	056	SAT	088	TAP	120	LUG	152	PUT	184	ALP
025	CON	057	PUB	089	VIN	121	LOT	153	YES		
026	OPA	058	SET	090	CUT	122	VIN	154	WAS		
027	RAF	059	SAF	091	ONE	123	CUT	155	JAG		
028	SOL	060	RAN	092	BOP	124	BOP	156	WAS		
029	DAT	061	SOL	093	SIN	125	BOP	157	CAB		
030	TRY	062	LET	094	JAB	126	WAB	158	PRY		
031	PUS	063	CAN	095	LET	127	TEN	159	BAT		

RECOGNITION TASK LIST NO. 188

Auditory ☐
Visual ☐

School______________________ Grade___ Reading Level___

S No.___ Name______________________ Date__________

		032	ONE	064	DOT	096	HOM	128	PUT	160	TAD
001	DUB	033	SAG	065	ONE	097	MEX	129	AND	161	CUR
002	PIN	034	FLY	066	JOT	098	[illegible]	130	FAE	162	FAD
003	HER	035	ORB	067	DOT	099	HIM	131	MEX	163	JEX
004	LEP	036	SUN	068	WAR	100	LOG	132	FEN	164	LUN
005	ERG	037	YES	069	JOT	101	BAG	133	ADO	165	FEN
006	DUG	038	OVA	070	ABY	102	HAT	134	AND	166	CUR
007	FAF	039	TAF	071	DOG	103	RAF	135	WAS	167	FAD
008	CUN	040	FAF	072	WAS	104	TOD	136	ADO	168	NEP
009	LOP	041	TEB	073	LOT	105	WAS	137	TOD	169	RUN
010	HOO	042	VOT	074	SOT	106	SHE	138	VIM	170	FID
011	PIN	043	HOO	075	HOB	107	YET	139	CUT	171	NEP
012	LOP	044	TAF	076	LOT	108	HIM	140	TUD	172	RUN
013	CUN	045	SUN	077	CUD	109	ORE	141	FOR	173	RUG
014	ERG	046	DIB	078	SOL	110	LOB	142	TAB	174	HAD
015	RAN	047	OVA	079	HOM	111	PUT	143	JAB	175	GET
016	SAG	048	OPA	080	CUD	112	RAF	144	WAS	176	SAT
017	TRY	049	CAN	081	ITS	113	END	145	TOD	177	GOB
018	RAN	050	TEB	082	CAN	114	MEX	146	FOR	178	RUG
019	FUR	051	OPA	083	SOL	115	SAC	147	VIM	179	HAD
020	HER	052	FUR	084	ITS	116	END	148	CUT	180	GOB
021	LEP	053	RAN	085	IFY	117	ORG	149	FIP	181	FAS
022	HOT	054	YES	086	ARM	118	BAG	150	ORG	182	NOL
023	SOP	055	FAT	087	ABY	119	IRK	151	TAB	183	GEN
024	SIT	056	SOP	088	DOG	120	SAC	152	IRK	184	FAS
025	VOT	057	SUT	089	NAF	121	PAN	153	FID		
026	TRY	058	HUB	090	ALS	122	RAF	154	FIP		
027	HOT	059	WAR	091	LOG	123	MOB	155	LUN		
028	DEN	060	FAT	092	PET	124	YET	156	LET		
029	SIT	061	DEN	093	HAT	125	PET	157	TAD		
030	ORB	062	ILK	094	IFY	126	JAG	158	JEX		
031	FLY	063	DIB	095	ILK	127	LOB	159	LET		

RECOGNITION TASK LIST NO. 104

Auditory ☐
Visual ☐

School____________________ Grade___ Reading Level___

S No.___ Name________________ ____ Date__________

	032 HOT	064 OPA	096 FAF	128 HIS	160 ONE
001 FID	033 FUN	065 HER	097 HEN	129 CON	161 GIT
002 GAV	034 FID	066 POS	098 FEN	130 CUT	162 IFY
003 ASU	035 HOT	067 DUB	099 PRY	131 PIN	163 JIB
004 HAD	036 ASU	068 AIK	100 HEN	132 VIN	164 SOL
005 FOD	037 NOL	069 RED	101 GAB	133 CUT	165 ONE
006 TRY	038 FOD	070 OVA	102 RED	134 CUD	166 JIB
007 SIM	039 NAM	071 CAB	103 JIT	135 ORG	167 NEB
008 NAS	040 LUN	072 DAC	104 CAB	136 PIN	168 ERG
009 RUN	041 NEP	073 HUB	105 FAB	137 HIS	169 SOL
010 HOD	042 TUD	074 GET	106 GAB	138 ORG	170 PAB
011 GAV	043 HOD	075 POS	107 ADD	139 HEN	171 ERG
012 GAM	044 NAM	076 DUB	108 FAR	140 AFT	172 GAT
013 NAS	045 GAM	077 DAC	109 LUG	141 ORN	173 ENG
014 PRO	046 FAT	078 FIN	110 TOD	142 OLD	174 ORB
015 FAD	047 PRO	079 ANY	111 FIN	143 HAS	175 GAT
016 SIM	048 HER	080 SUN	112 ANY	144 SOP	176 ANO
017 LET	049 LUN	081 HIM	113 FAF	145 DOG	177 ORB
018 CAD	050 TEB	082 HUG	114 HIM	146 CON	178 END
019 MAN	051 CAD	083 SUN	115 FEN	147 FLY	179 ANG
020 FAD	052 CAN	084 SUP	116 PRY	148 CAN	180 SET
021 HAD	053 TEB	085 CAN	117 SUP	149 DIB	181 TAD
022 LET	054 NOL	086 RUB	118 LUG	150 DOG	182 HIT
023 TRY	055 JEK	087 SAT	119 TOD	151 OLD	183 SOT
024 BLY	056 HAT	088 SAT	120 OAT	152 HAS	184 TAD
025 TUD	057 GET	089 HAT	121 LEP	153 CAN	185 SET
026 RUN	058 NEP	090 ADD	122 HEN	154 DIB	
027 BLY	059 ASK	091 RUB	123 VIN	155 GAB	
028 MAN	060 JEK	092 PIF	124 ORN	156 FLY	
029 GAD	061 OVA	093 SAT	125 CUD	157 AFT	
030 FUN	062 GAD	094 JIT	126 LEP	158 BAD	
031 OPA	063 FAT	095 PIP	127 SOP	159 IFY	

RECOGNITION TASK LIST NO. 107

Auditory ☐
Visual ☐

School____________________ Grade____ Reading Level____

S No.____ Name____________________ Date____________

001 CUN
002 ASK
003 WAN
004 ADO
005 DUB
006 FOO
007 ASK
008 FAS
009 FOO
010 NEP
011 MAF
012 NUB
013 FAS
014 TAB
015 NEP
016 RAN
017 GOT
018 CUN
019 HIT
020 MAF
021 ADO
022 GOT
023 TAB
024 HIT
025 OVA
026 HER
027 CUR
028 CAR
029 NUB
030 HAS
031 NAR

032 CUR
033 RED
034 NAN
035 HER
036 WAN
037 LOP
038 DUB
039 HAS
040 CAN
041 APT
042 OVA
043 TEB
044 CAN
045 CAM
046 BUT
047 PUT
048 TAD
049 RAN
050 PUT
051 HOD
052 TEB
053 CAN
054 FUN
055 IFY
056 ROG
057 SAZ
058 APT
059 FAT
060 HOD
061 CAR
062 PEB
063 MEN

064 IFY
065 HAT
066 RED
067 PEB
068 HAG
069 RAF
070 LOP
071 LOB
072 BAB
073 ROG
074 HAT
075 BLY
076 FAT
077 WAS
078 SIT
079 BUT
080 MEN
081 TAD
082 FAF
083 HIS
084 IRK
085 HAG
086 RAF
087 FUN
088 LET
089 SPE
090 SAZ
091 FAF
092 BLY
093 JAB
094 PLY
095 SIT

096 VIT
097 LET
098 ILK
099 PLY
100 HIS
101 LOT
102 JAB
103 GUN
104 LOB
105 BAB
106 LOT
107 ILK
108 DAY
109 DEN
110 WAS
111 VUT
112 GAR
113 VIT
114 DEN
115 WAR
116 HIM
117 IRK
118 VUM
119 NOL
120 GUM
121 SAF
122 SPE
123 OPA
124 NOL
125 RUN
126 OPA
127 VOR

128 VOT
129 GAB
130 GUN
131 JOP
132 PRY
133 HIM
134 GAB
135 FAR
136 JIB
137 PRY
138 FAR
139 FUN
140 GAD
141 DAY
142 FIP
143 GAD
144 DOG
145 FIP
146 GAT
147 POS
148 FUN
149 DOG
150 GAS
151 GAT
152 POS
153 JIB
154 SAP
155 PIP
156 GOB
157 DID
158 PIP
159 ORG

160 DID
161 CUD
162 FID
163 PRO
164 JOP
165 GOB
166 PRO
167 OLD
168 GET
169 FIB
170 CUD
171 GET
172 FIB
173 AND
174 KEN
175 VET
176 AND
177 KEN
178 YET
179 HUB
180 ASU
181 FRY
182 HUB
183 ASU

6a. MAIN RECOGNITION EXPERIMENT

INSTRUCTIONS - AUDITORY

Child

This is a game to find out how______ graders hear things. First of all you'll put on some earphones and then there will be a quiet period. That will mean get ready. Then you'll hear a man's voice saying something like "SEV". We call this a pattern. As the game goes on you will have heard some of the patterns earlier over your earphones. If you think you have heard a pattern earlier in this game say "old". If you think you haven't heard it before in this game say "new". The first time you hear a pattern over your earphones it will be new. So say "new" out loud. If you hear it again over your earphones it will be old. So say "old" out loud. Some patterns will be new; some will be old. There will be as many old patterns as there are new patterns. Each time you hear a pattern say "old" or say "new". You must answer each time you hear a pattern. Be sure to answer before the next pattern comes on. Say "old" or "new" in a loud voice. Let's try some for practice first. Are you ready? That was fine. Are there any questions? All right. That was just for practice. Now we will begin on the real list.

Adult

This is an experiment to find out how people hear things. First of all you'll put on some earphones and then there will be a quiet period. That will mean get ready. Then you'll hear a man's voice saying something like "SEV". We call this a pattern. As the experiment goes on you will have heard some of the patterns earlier over the earphones. If you think you have heard a pattern earlier in this experiment say "old". If you think you haven't heard it before in this experiment say "new". The first time you hear a pattern over your earphones it will be new. So say "new" out loud. If you hear it again over your earphones it will be old. So say "old" out loud. Some patterns will be new; some will be old. There will be as many old patterns as there are new patterns. Each time you hear a pattern say "old" or say "new". You must answer each time you hear a pattern. Be sure to answer before the next pattern comes on. Say "old" or "new" in a loud voice. Let's try some for practice first. Are you ready? That was fine. Are there any questions? All right. That was just for practice. Now we will begin on the real list.

6b. MAIN RECOGNITION EXPERIMENT

INSTRUCTIONS - VISUAL

Child

This is a game to find out how ________ graders see things. First of all I'll turn on the projector and say "get ready". Then you'll see 3 letters in a row on the screen. We call this a pattern. As the game goes on you will have seen some of the patterns before on the screen. If you think you have seen a pattern before on the screen, say "old". If you think you haven't seen it before on this screen, say "new". The first time you see a pattern it will be new. So say "new" out loud. If you see it again on the screen it will be old. So say "old" out loud. Some patterns will be new; some will be old. There will be as many old patterns as there are new patterns. Each time a pattern comes on the screen say "old" or say "new". You must answer each time you see a pattern on the screen. Be sure to answer before the next pattern comes on. Say "old" or "new" in a loud voice because the projector is very noisy. Let's try some for practice first. Are you ready? That was fine. Are there any questions? All right. That was just for practice. One more thing. Several times during the game there will be a very long pause between patterns because I must put in a new box of slides. Keep your eyes on the screen all the time because from now on, regardless of the length of the pause, it will be one long list.

Adult

This is an experiment to find out how people see things. First of all I'll turn on the projector and say "get ready". Then you'll see 3 letters in a row on the screen. We call this a pattern. As the experiment goes on you will have seen some of the patterns before on the screen. If you think you have seen a pattern before on the screen, say "old". If you think you haven't seen it before on this screen, say "new". The first time you see a pattern it will be new. So say "new" out loud. If you see it again on the screen it will be old. So say "old" out loud. Some patterns will be new; some will be old. There will be as many old patterns as there are new patterns. Each time a pattern comes on the screen say "old" or say "new". You must answer each time you see a pattern on the screen. Be sure to answer before the next pattern comes on. Say "old" or "new" in a loud voice because the projector is very noisy. Let's try some for practice first. Are you ready? That was fine. Are there any questions? All right. That was just for practice. One more thing. Several times during the experiment there will be a very long pause between patterns because I must put in a new box of slides. Keep your eyes on the screen all the time because from now on, regardless of the length of the pause, it will be one long list.

7. REFERENCES TO TEXT ANALYZED FOR READERS AND FREE-CHOICE TEXTS

1. Ginn Basic Readers:

   Level 1.2: On Cherry Street, 1957, pp. 228.
   Level 2.1: We Are Neighbors, 1957, pp. 269.
   Level 3.1: Finding New Neighbors, 1957, pp. 324.
   Level 5 : Trails to Treasure, 1956, pp. 512.

2. Sheldon Basic Reading Series:

   Level 1 : Our Town, 1957, pp. 192.
   Level 3.1: Magic Windows, 1957, pp. 272.
   Level 5 : Finding the Way, 1957, pp. 352.

3. Free Reading Choices:

   Level 1:
   1) Theodore Turtle (Ellen MacGregor)
   2) The Bears on Hemlock Mountain (Alice Dalgliesh)
   3) The 500 Hats of Barthomew Cubbins (Dr. Seuss)

   Level 3:
   1) The Courage of Sarah Noble (Alice Dalgliesh)
   2) The Emperor's New Clothes (H. C. Andersen)
   3) Winnie - the - Pooh (A. A. Milne)
   4) Fast Sooner Hound (Arna Bontemps and Jack Conroy)

   Level 5:
   1) Mary Poppins (P. L. Travers)
   2) Dr. Doolittle (H. Lofting)
   3) Alice in Wonderland (Lewis Carroll)

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Aborn, M. and Rubenstein, H., Information Theory and Immediate Recall, J. Exp. Psychol., 1952, 44, 260-266.

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